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Description of three new muricids (Gastropoda: Muricidae: Muricinae) from the Philippines and Fiji

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ABSTRACT

Three new species are described from the Philippines and Fiji, one in the genus *Chicomurex* Arakawa, 1964 and two in *Chicoreus* (*Triplex*) Perry, 1911. *Chicomurex excelsus* new species from the Philippines is compared with *C. gloriosus* (Shikama, 1977), *C. pseudosuperbus* Houart, Moe, and Chen, 2015, and *C. venustulus* (Rehder and Wilson, 1975), species that are or were confused with the new species. *Chicoreus* (*Triplex*) *kaitomoei* new species from Fiji is compared with *C. aculeatus* (Lamarck, 1822), *C. rossiteri* (Crosse, 1872), *C. nobilis* Shikama, 1977, *C. ryukyuensis* Shikama, 1978, and *C. cloveri* Houart, 1985; two of these were confused with the new species by recent authors and the others have a few similar shell characters. *Chicoreus* (*Triplex*) *aquilus* new species from Fiji is compared with *C. rubescens* (Broderip, 1833), *C. strigatus* (Reeve, 1849), *C. paini* Houart, 1983, and *C. dodongi* Houart, 1995, species with an approximately similar size, a similarly narrow shell, high spire, moderately long siphonal canal, and small aperture.

Additional Keywords: Neogastropoda, *Chicomurex*, *Chicoreus* (*Triplex*), Philippine Islands, Fijian Archipelago, new species

INTRODUCTION

The genus *Chicomurex* Arakawa, 1964, which is restricted to the Indo-West Pacific, was recognized as a separate genus by Houart (1992: 115) based on shell and radular characters. The genus then included seven species: *C. elliscrossi* (Fair, 1974), *C. laciniatus* (Sowerby II, 1841), *C. problematicus* (Lan, 1981), *C. protoglobosus* Houart, 1992, *C. superbus* (Sowerby III, 1889), *C. turschi* (Houart, 1981), and *C. venustulus* (Rehder and Wilson, 1975). Five additional species were described by Houart (2013) and Houart et al. (2014; 2015). Houart et al. (2014) considered *C. problematicus* a junior subjective synonym of *C. superbus* and Houart et al. (2015) reinstated the name *C. gloriosus* (Shikama, 1977). The genus thus currently contains 13 Recent species: *C. elliscrossi* (Fair, 1974), Japan; *C. globus* Houart, Moe, and Chen, 2015, New Caledonia, Vanuatu, to Okinawa, Japan; *C. gloriosus* (Shikama, 1977), Indo-West Pacific; *C. laciniatus* (Sowerby II, 1841), Indo-West Pacific; *C. lani* Houart, Moe, and Chen, 2014, northeastern Australia, New Caledonia, Vanuatu, to southern Japan; *C. protoglobosus*, New Caledonia; *C. pseudosuperbus* Houart, Moe, and Chen, 2015, Queensland, Australia, New Caledonia, to southern Japan; *C. ritae* Houart, 2013, Philippines; *C. rosadoi* Houart, 1999, Mozambique; *C. superbus*, Queensland, Australia to southern Japan; *C. tagaroae* Houart, 2013, Philippines; *C. turschi*, Indo-West Pacific; and *C. venustulus*, Marquesas. A fourteenth species is here described based on materials from the Philippines and the Marshall Islands. A molecular phylogeny of the genus *Chicomurex* is currently being prepared (Chen et al., in prep.). For those species with data available, including the recently described *C. lani*, *C. pseudosuperbus*, and *C. globus*, molecular results agree well with morphological identification in terms of species-level separation, indicating that the shell characters used to separate *Chicomurex* species are effective and accurate (C. Chen, pers. comm.).

Triplex Perry, 1811 was considered separate from *Chicoreus* sensu stricto by Houart (1992: 34) and was then used as subgenus. It currently includes more than 50 species in the Indo-West Pacific. Two additional species from Fiji are described here, in two different groups as established by Houart (1992). Houart and Héros (2008) estimated the number of muricids in Fiji to be 95, and the current paper brings that number to 97. One of the two new species described herein from Fiji has previously been misidentified as *Chicoreus* (*Triplex*) *nobilis* Shikama, 1977 by Houart (1992: 100 [in part], fig. 210 [only]) and Houart and Héros (2008: 443, fig. 1I). It is important, however, to note that the typical *C. nobilis* does indeed also occur in Fiji (Figure 28).

MATERIALS AND METHODS

Most of the material studied here comes from the authors' private collections. The two new species of *Chicoreus*

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were collected a few years ago in Suva, Fiji and the new species of *Chicomurex* from the Philippines was regularly misidentified as *C. gloriosus* (Shikama, 1977) or *C. venustulus* (Rehder and Wilson, 1975) by collectors in the Philippines. Additional specimens originate from materials gathered during two cruises organized by MNHN and IRD in southern Viti Levu (SUVA 2 and SUVA 4 cruises) in 1998 and 1999. The SUVA 2 Cruise was carried out in the Fijian Archipelago from 10–23 October 1998. Dredging, trawling, and Smith-McIntyre grab-sampling methods yielded 85 samples in the South and West lagoon of Vitu Levu Island. The SUVA 4 Cruise was also carried out in the Fijian Archipelago from 19–27 September 1999. The purpose of that mission was to complete the benthos sampling started in 1998. Three types of dredging and trawling methods, including Smith-McIntyre grab, Warén dredge and beam trawl, were used for 39 stations. Sampling was carried out in Suva Harbor, Lauthala Bay, and Rewa River, others in Beqa Lagoon and Pacific Harbor Bay.

The characters used to describe the shell morphology herein include the general aspect of the shell, its shape and size, color, shape of the spire and number of protoconch and teleoconch whorls, features of the protoconch, shape of the teleoconch whorls and features or form of the suture and of the subsutural ramp, of axial and spiral sculpture, the aperture, and siphonal canal. Unless otherwise mentioned, the species descriptions are based on the holotype and the paratypes. The method for determining diameter, height and counting the number of protoconch whorls is shown in Figure 1. We used the same method as that illustrated and used by Bouchet and Kantor (2004).

The bathymetric range given here is provided using the inner values of the recorded depth: the largest value of the minimum values and the lowest value of the maximum values of all the recorded ranges. This is the same as the concept of "confirmed bathymetric range" (Harasewych, 2011).

Abbreviations of repository collections are: **CC:** collection of Chong Chen; **CM:** collection of Christopher Moe; **IRSNB:** Institut royal des Sciences naturelles de Belgique, Bruxelles, Belgium; **MNHN:** Muséum national d'Histoire naturelle, Paris, France; **RH:** collection of Roland Houart; **SJ:** collection of Scott Johnson. Other abbreviations used in the text are: **DW:** Warén Dredge; **IRD:** Institut de Recherche pour le Développement, France; **ad:** adult specimen; **juv:** juvenile specimen; **dd:** empty shell; **lv:** live-collected specimen.

TERMINOLOGY USED TO DESCRIBE SPIRAL CORDS AND APERTURAL DENTICLES (AFTER MERLE 2001 AND 2005) (Figures 2–6) (Terminology in parentheses: erratic feature): **Spiral cords: ab:** abapical (or abapertural); **abis:** abapical infrasutural secondary cord (on subsutural ramp); **ABP:** abapertural primary cord on the siphonal canal; **abs:** abapertural secondary cord on the siphonal canal; **ad:** adapical (or adapertural); **adis:** adapical infrasutural secondary cord (on subsutural ramp); **ADP:** adapertural primary cord on the siphonal canal; **ads:** adapertural secondary cord on the siphonal canal; **IP:** infrasutural primary cord (primary cord on subsutural ramp); **MP:** median primary cord on the siphonal canal; **ms:** median secondary cord on the siphonal canal; **P:** primary cord; **P1:** shoulder cord; **P2–P6:** primary cords of the convex part of the teleoconch whorl; **s:** secondary cord; **s1–s6:** secondary cords of the convex part of the teleoconch whorl (example: s1 = secondary cord between P1 and P2; s2 = secondary cord between P2 and P3, etc.); **t:** tertiary cord. **Aperture: D1 to D6.** Abapical denticles; **ID.** Infrasutural denticle.

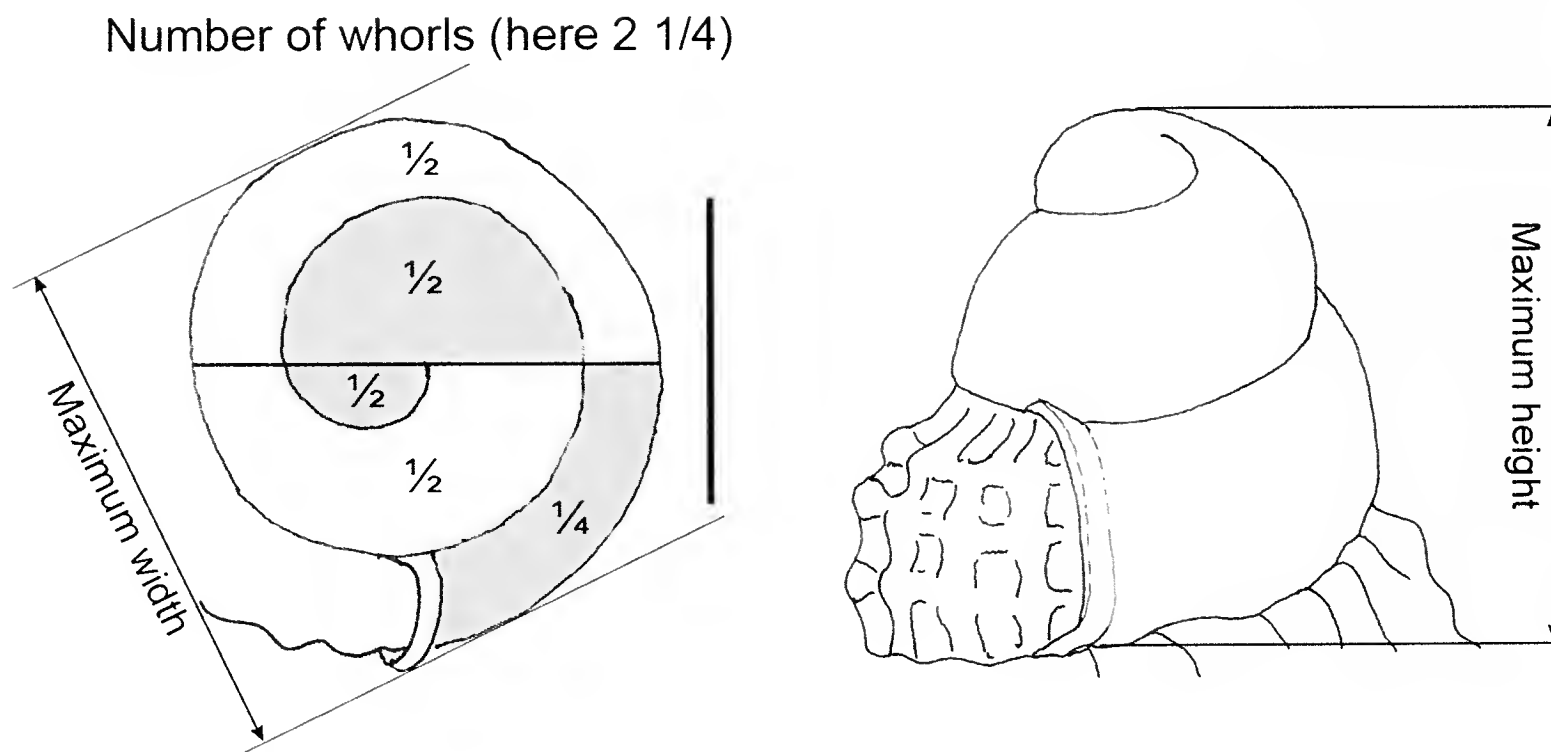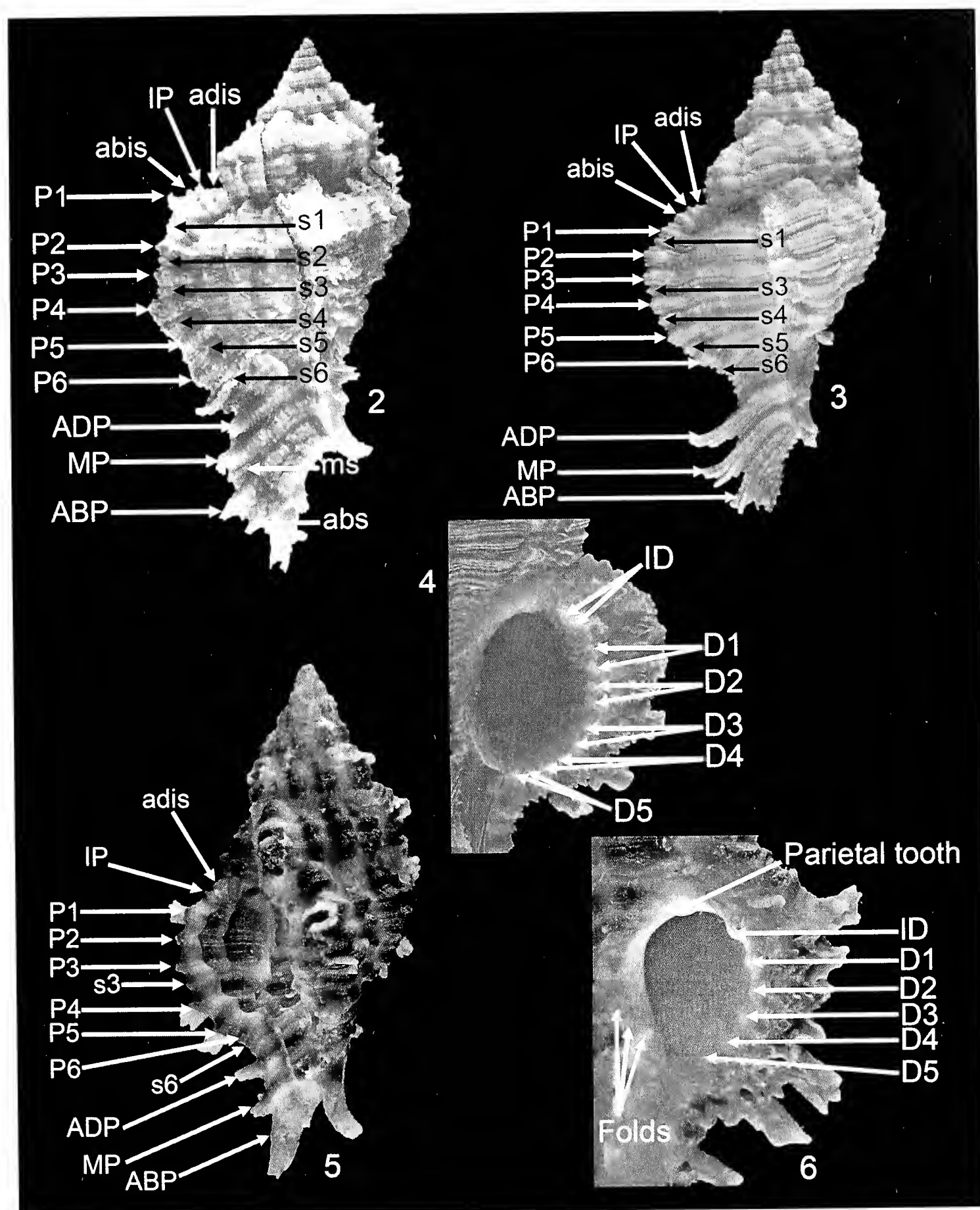## Number of whorls (here 2 1/4)

Figure 1. Method for determining diameter, height and counting the number of protoconch whorls Scale bar = 500 μm.

Figures 2–6. Spiral cords and aperture morphology. **2. *Chicomurex excelsus* new species**. Holotype, MNHN IM-2000-33591. **3–4. *Chicoreus (Triplex) kaitomoei* new species.** Holotype, MNHN IM-2000-33592. **5–6. *Chicoreus (Triplex) aquilus* new species.** Holotype MNHN IM-2000-33593. (See Materials and Methods for abbreviation explanations.)

SYSTEMATICS

Family Muricidae Rafinesque, 1815
Subfamily Muricinae Rafinesque, 1815

Genus *Chicomurex* Arakawa, 1964

Type Species: *Murex superbus* Sowerby, 1889, Recent, Philippines (original designation)

***Chicomurex excelsus* new species**
(Figures 2, 7–15)

Chicomurex venustulus.—Merle et al., 2011: pl. 77, fig. 16
    (only) (not *Chicoreus venustulus* Rehder and Wilson,
    1975).

Description: Shell medium-sized for genus, up to 58.3 mm in length (paratype CM). Length/width ratio 1.8–2.1. Lanceolate, angular, broadly ovate, weakly spinose, squamous and nodose. Lightly built. Subsutural ramp narrow, weakly sloping, convex. Protoconch and first and second teleoconch whorls light pink. Subsutural ramp to P2 cream or light tan with traces of light brown on spiral cords; orange or dark brown between P2 and P6 or between P2 and ABP; P6 and s6 occasionally white. One paratype (RH) creamy white with some orange spots between P2 and s6, s6 light orange; creamy white between s6 and tip of siphonal canal. Aperture white with narrow brown line on outer apertural edge, line often extending on right edge to tip of siphonal canal; ventral left part of siphonal canal white. Spire high with 2+ protoconch whorls (partly broken in a paratype, eroded or broken in other specimens) and up to 7 broad, weakly convex, angular, weakly shouldered, spinose and nodose whorls. Suture adpressed. Protoconch partly preserved in a paratype (Figure 14, CM) with narrow abapical keel on last whorl, and penultimate whorl partly broken. Axial sculpture of teleoconch whorls consisting of low, strong, narrow, rounded, nodose ribs and high, narrow, rounded, weakly spinose varices. First whorl with 10 or 11 axial ribs, starting varices with 2 or 3 intervariceal ribs from second to penultimate whorl; ribs increasing in strength abapically. Last whorl with 3 narrow, rounded, weakly spinose varices, webbed on abapical part of whorl, webbing extending on siphonal canal. Intervarical sculpture of last whorl consisting of two moderately narrow, high axial ribs with higher node close to preceding varix. Spiral sculpture of primary, secondary and tertiary nodose cords. Primary cords moderately high and broad; P4–P6 slightly broader and higher, followed by ADP, MP and ABP on siphonal canal, similar in strength to P4–P6; ADP spine occasionally shorter. Secondary cords narrow, except s6 of similar in strength to P1–P3. Tertiary cords very narrow. Aperture relatively small, ovate. Columellar lip narrow, smooth abapically, with weak folds adapically and low parietal tooth. Rim partially erect, a small portion adherent at adapical extremity. Anal notch shallow, broad. Outer lip erect,

crenulated, with very weak, narrow lirae within. Siphonal canal long, 40–43% of shell length, broad, weakly dorsally recurved, narrowly open, with dorsally recurved, webbed ADP, (ads), MP, ms, ABP and bs spines. Operculum light or dark brown, ovate with apical nucleus.
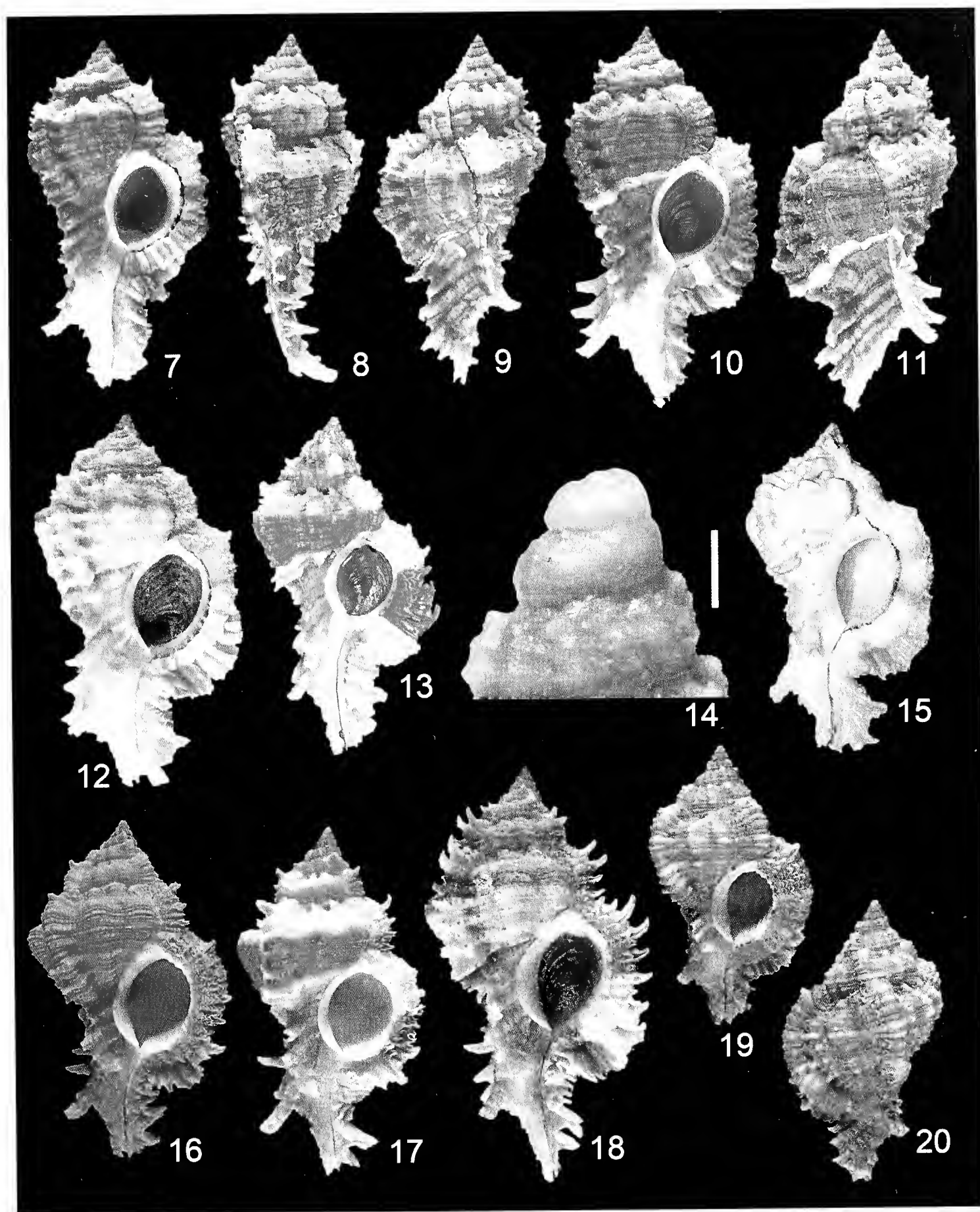
Type Material: Holotype: MNHN IM-2000-33591, from type locality; **paratypes:** Philippines, Southwest of Bohol, Balicasag Island, by tangle nets, 150 m, lv, ad, 1 RH; Philippines, Bohol Island, 200 m, lv, ad, 1 CM; Philippines, Balut Island, by tangle nets, 200 m, lv, ad, 1 CC; Philippines, Balut Island, Tinina, by tangle nets, 150–300m, lv, ad, 1 CC.

Type Locality: Philippines, Bohol Island.

Other Material Examined: Kwajalein Atoll, Marshall Islands, 60 m, dead in octopus piles on the Oceanside drop off near Enubuj (Carlson) Island, SJ (10 dd, ad) CM (3 dd, ad).

Distribution: Southern Philippines Islands and Kwajalein Atoll, Marshall Islands, living at 150–200 m.

Remarks: A paratype (CM) of *Chicomurex excelsus* new species has a partly preserved protoconch with intact last and partly intact penultimate whorls. The morphology of these whorls and the presence of a narrow keel on the abapical part of the last whorl (Figure 14) suggest a conical protoconch as observed in a few other species, namely *C. laciniatus*, *C. superbus*, *C. venustulus*, *C. gloriosus*, *C. lani*, *C. globus,* and *C. pseudosuperbus*. All the other *Chicomurex* species have a rounded, paucispiral protoconch. *Chicomurex excelsus* new species is closest to *C. gloriosus* (Figures 16–17) but consistently differs by having a lower spire in relation to the shell length (approximately 35% of total shell length, as opposed to 38–40% in *C. gloriosus*) and a longer siphonal canal (40–43% of total shell length compared to 35–40% in *C. gloriosus*). It also has a less rounded, more angular last teleoconch whorl, narrower axial varices, lower intervarical axial nodes, a less scabrous shell and webbed spines on the siphonal canal whereas these are never webbed in *C. gloriosus*. A recently described species, *C. pseudosuperbus* (Figure 18), is also similar, but *C. excelsus* new species differs by having a smaller shell compared to the number of teleoconch whorls, a less rounded teleoconch whorl, a slightly lower spire, and a less scabrous shell with strongly webbed spines on the siphonal canal instead of separate long spines as in *C. pseudosuperbus*. *Chicomurex excelsus* new species further differs from *C. venustulus* (Figures 19–20), a species currently known only from the Marquesas, by having a larger shell, reaching almost twice the length of an adult *C. venustulus* with a same number of teleoconch whorls. *Chicomurex excelsus* new species also has a less rounded last teleoconch whorl, a less scabrous shell and a comparatively longer siphonal canal. A specimen of *Chicomurex excelsus* new species from the Kwajalein Atoll (Figure 15) has a broader last teleoconch whorl

Figures 7–20. *Chicomurex* species. **7–15. *Chicomurex excelsus* new species. 7–9.** Holotype, MNHN IM-2000-33591, Philippines, Bohol Island, 54.8 mm. **10–11, 14.** Paratype CM, Philippines, Bohol Island, 200 m, 58.3 mm. **12.** Paratype RH, Philippines, Southwest of Bohol, Balicasag Island, by tangle nets, 150 m, 55.3 mm. **13.** Paratype CC, Philippines, Balut Island, by tangle nets, 46.1 mm; **15.** CM, Marshall Islands, Kwajalein Atoll, 43.1 mm. **16–17.** *Chicomurex gloriosus* (Shikama, 1977), Balut Island, Philippines (**16.** 49.1 mm; **17.** 50.9 mm). **18.** *Chicomurex pseudosuperbus* Houart, Moe, and Chen, 2015, RH, Philippines, Bohol, Kalituban Iisland, tangle nets, 90 m, 71.6 mm. **19–20.** *Chicomurex venustulus* (Rehder and Wilson, 1975), RH, Marquesas, Nuku Hiva, 104–109 m, 32.4 mm. Scale bar = 500 µm.

compared to other specimens but all other features match with the above description.

Etymology: Latin *excelsus*, high, lofty, distinguished; named for the distinctive and beautiful shell morphology.

Japanese Name: *"Furisode-Senju,"* フリソデセンジュ, after the "swinging-sleeves" style kimono known as "furisode", which resembles the webbed siphonal canal in this species. "Senju" is a general vernacular term for muricids with spinous and frondose varices, literally meaning "thousand-hands".

Chicoreus (Triplex) kaitomoei new species
(Figures 3–4, 21–26)

Chicoreus aculeatus.—Cernohorsky, 1967a: 117, pl. 14, fig. 5, text fig. 1; Cernohorsky, 1967b: 118 (in part), pl. 25, fig. 147; Cernohorsky, 1985: 47 (in part), fig. 3 (only) (not *Murex aculeatus* Lamarck, 1822).
Chicoreus (Triplex) nobilis.—Houart, 1992: 100 (in part), fig. 210 (only); Houart and Héros, 2008: 443, fig. 1I (not *Chicoreus nobilis* Shikama, 1977).

Description: Shell small for genus, up to 32.8 mm in length (paratype CM). Length/width ratio 1.7–2.0. Slender, lanceolate, broadly ovate, heavy, weakly spinose and nodose. Subsutural ramp narrow, weakly sloping, convex. Shell entirely light-orange. Aperture white within; columellar lip and narrow band in outer lip pink. Spire high with 2 protoconch whorls and teleoconch up to 7 broad, strongly convex, strongly shouldered, nodose whorls. Suture adpressed. Protoconch small, bulbous. Whorls rounded, smooth, last whorl flattened, width and height 700–800 μm. Terminal lip delicate, thin, erect, curved. Axial sculpture of teleoconch whorls consisting of ribs and varices. First whorl with 12–14 narrow ribs, second whorl starting varices with 2 or 3 broad intervariceal ribs. Third to last whorl with 3 varices and 2 intervariceal ribs. Varices increasing obviously in width and strength abapically. Last whorl with 3 broad varices and two broad intervariceal ribs. Spiral sculpture of primary, secondary, tertiary cords and numerous squamous threads. First to third whorl with visible, narrow P1–P3 or P1–P4, starting IP from second whorl. Spiral cords increasing in width from fourth whorl, then splitting in several threads. Top thread weakly broader with two smaller threads on each side. Other spiral sculpture of narrow, secondary cords, occasionally with additional tertiary cords. P2–P5 of same strength; P1 and P6 narrower. ADP, MP, and ABP cords also topped with several threads, giving rise to long, frondose spines. Aperture large, ovate. Columellar lip narrow, weakly flaring, smooth with low parietal tooth at adapical extremity. Rim partially erect, a small portion adherent to adapical extremity. Anal notch narrow, moderately deep. Outer lip erect, crenulated, with strong, narrow, split denticles extending on a short distance within as narrow lirae: 1D, D1–D5 split. Siphonal canal moderately

long, 36–38% of shell length, narrow, strongly dorsally recurved at tip, narrowly open, with 3 frondose, abapically bent, long spines, situated on abapical part of canal, gradually decreasing in length abapically. Operculum light or dark brown with apical nucleus.
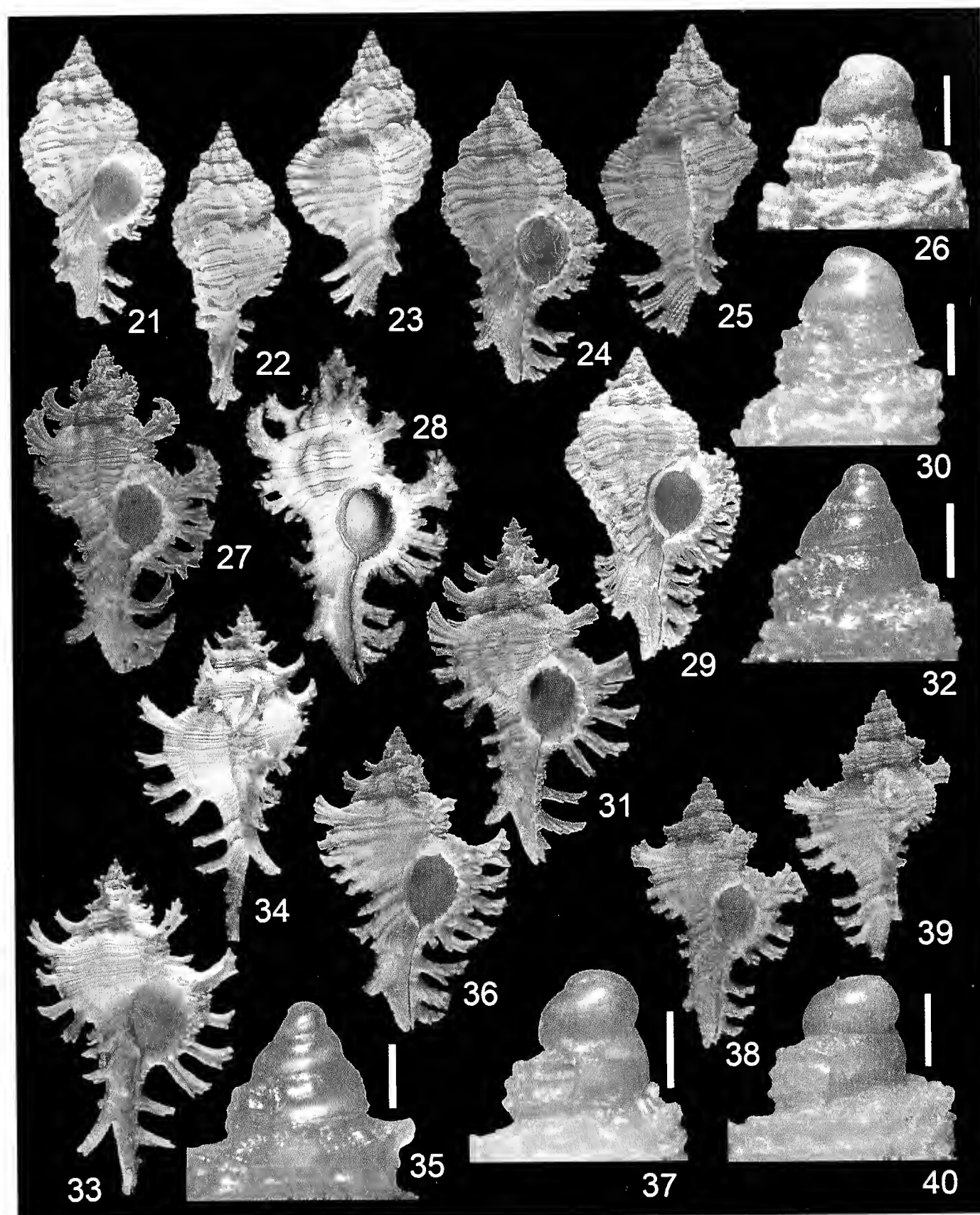
Type Material: Holotype: MNHN IM-2000-33592lv, ad (from type locality); **paratypes:** lv, juv, 1 IRSNB 1G. 33491/MT. 3596; lv, ad, 5 CM (from type locality); lv, juv, 1 CC (from type locality); Fiji, Viti Levu, Mbenga Island, 9 m, under coral rubble, 2 lv, ad, 1 lv, juv (RH); SUVA 4: Fiji, Viti Levu, stn DW08, 18°22′ S, 178°02′ E, 28–30 m, juv, lv and dd, 8 MNHN IM-2008-991.

Type Locality: Fiji, southern Viti Levu, Suva area, drop off in 31–40 m.

Other Material Examined: SUVA 2: Fiji, southern Viti Levu, stn DW 62, 17°48′ S, 177°13′ E, 32 m, 1 dd, MNHN IM-2008-992; SUVA 4, Fiji, Viti Levu, stn DW 22, 18°27′ S, 177°59′ E, 32–36 m, 1 lv, juv, MNHN 1M-2008-990; stn DW 26, 18°24′ S, 178°05′ E, 42–43 m, 1 dd, MNHN IM-2008-989 (illustrated in Houart and Héros, 2008: fig. 1I, as *Chicoreus nobilis*).

Distribution: Fijian Archipelago, southern Viti Levu, Living at 9–30 m.

Remarks: *Chicoreus (Triplex) kaitomoei* new species is here included in a group numbered "group 7" in Houart (1992: 99). The shells of these species are white, pinkish or yellowish, are relatively small and with short variceal frondose spines. Both lecithotrophic and planctotrophic larval development are observed. "Group 7" currently includes *Chicoreus (Triplex) aculeatus* (Lamarck, 1822), *C. rossiteri* (Crosse, 1872), *C. nobilis*, *C. ryukyuensis* Shikama, 1978, *C. cloveri* Houart, 1985, *C. crosnieri* Houart, 1985, *C. fosterorum* Houart, 1989, *C. zululandensis* Houart, 1989, and *C. kantori* Houart and Héros, 2013 (here newly assigned to that group). *Chicoreus kaitomoei* new species was confused with *C. aculeatus* and *C. nobilis* in the recent literature. However, *C. kaitomoei* differs from both species by having a paucispiral, rounded protoconch (Figure 26) as opposed to a multispiral and conical protoconch with sinusigeral terminal lip in *C. aculeatus* (Figure 32) and *C. nobilis* (Figure 30) implying a planctotrophic larval development in both species, rather than lecithotrophic in *C. kaitomoei* new species The same different protoconch morphology and larval development separate *C. rossiteri* (Figure 35) from our new species. In addition, *C. kaitomoei* new species differs from *C. nobilis* (Figures 27–30) by having a comparatively smaller shell with shorter variceal spines, especially those extending from P1, P2, and P3, even in a short spined form of *C. nobilis* from the Coral Sea (Figure 29). The P6 spine is also obviously relatively longer and broader in *C. kaitomoei* new species while very short and narrow in *C. nobilis*. *Chicoreus kaitomoei* new species also differs from *C. nobilis* by having straight, abapically bent spines on the siphonal canal instead of

Figures 21–40. *Chicoreus* species. **21–26. *Chicoreus (Triplex) kaitomoei* new species. 21–25.** Fiji, southern Viti Levu, Suva area, drop off in 31–40 m. **21–23.** Holotype, MNHN IM-2000-33592, 30.8 mm. **24–25.** Paratype CM, 32.8 mm. **26.** Paratype RH, protoconch, Fiji, Viti Levu, off Mbengga Island, 9 m, under coral rubble. **27–30.** *Chicoreus (Triplex) nobilis* Shikama, 1977. **27.** RH, Philippines, Cebu, Sogod, tangle nets, 43.4 mm. **28.** CM, Fiji, southern Viti Levu, Suva area, drop off in 31–40 m, 43.7 mm. **29.** RH, Coral Sea, 64 m, 41.6 mm. **30.** RH, protoconch, Papua New Guinea, Hansa Bay (Madang Province), Laing Island, 45 m. **31–32.** *Chicoreus (Triplex) aculeatus* (Lamarck, 1822). **31.** RH, Philippines, Balicasag Island, tangle nets, 51.2 mm. **32.** Protoconch, Philippines, Siargao Island. **33–35.** *Chicoreus (Triplex) rossiteri* (Crosse, 1872). **33–34.** RH, Philippines, Bohol, Panglao, RH, 47.5 mm. **35.** RH, protoconch, Philippines, Cebu Island. **36–37.** *Chicoreus (Triplex) ryukyuensis* Shikama, 1978. **36.** RH, Japan, Okinawa, Seragaki Reef, 40–50 m, 33.1 mm. **37.** RH, protoconch, Guam, Hospital Point, 14–17 m. **38–40.** *Chicoreus (Triplex) cloveri* Houart, 1985. Mauritius, paratype RH, 23.5 mm. Scale bars = 500 μm.

long, strongly adapically curved fronded spines in *C. nobilis*. *Chicoreus kaitomoei* new species further differs from *C. aculeatus* (Figures 31–32), a widely distributed species across the Indo-West Pacific, by having relatively broader varices with shorter variceal spines, lower intervariceal ribs (consisting usually of a single high node in *C. aculeatus*), and also by having shorter, more abapically bent canal spines. From *C. rossiteri* (Figures 33–35) it differs also by having distinct protoconch morphology and comparatively broader axial varices with shorter spines, 2 or 3 intervariceal ribs instead of a single, strong node in *C. rossiteri*, rarely with an additional low ridge, and by having a shorter siphonal canal with abapically bent spines at the lower part of the canal rather than long spines distributed over the whole length of the canal in *C. rossiteri*. *Chicoreus kaitomoei* new species differs from *C. ryukyuensis* (Figures 36–37) by having a lower spire, broader axial varices, narrower primary spiral cords and abapically bent spines on the lower part of the siphonal canal opposed to upward recurved spines in the whole length of the canal in *C. ryukyuensis*. Lastly, *C. kaitomoei* new species differs from *C. cloveri* (Figures 38–40), a species endemic to Mauritius and surrounding areas, by having a comparatively larger shell with broader axial varices, broader primary spiral cords and a broader, relatively shorter siphonal canal with more heavily abapically bent spines.

Etymology: Named after Kaito Eyvindr Moe, son of the second author, Christopher Moe, hoping to infuse in him an interest in malacology and marine science.

Japanese Name: *"Kaito-Senju,"* カイトセンジュ, same etymology as above.

Chicoreus (Triplex) aquilus new species
(Figures 5–6, 41–43)

Description: Shell small for genus, 36.5 mm in length. Length/width ratio 2.0. Slender, lanceolate, broadly ovate, heavy, weakly spinose, and nodose. Subsutural ramp narrow, strongly sloping, convex.

Light tan with black varices and axial ribs; additional black spots on spiral cords; ventral left part of siphonal canal light tan. Aperture white with pinkish narrow line on outer edge of columellar lip, extending to tip of siphonal canal. Spire high, acute. Teleoconch of 7 broad, weakly shouldered, nodose, weakly spinose whorls. Suture adpressed. Protoconch unknown (eroded). Axial sculpture consisting of high, strong, nodose ribs and varices. First two teleoconch whorls partly eroded. Third to last whorl with narrow, weakly spinose varices and two broad, nodose axial ribs, extending from the suture. A third, smaller rib, close to succeeding varix. Spiral sculpture of high, rounded, narrow, nodose primary cords, narrow secondary cords, and a few obsolete tertiary cords or lirae. Third to penultimate whorl with adis, IP, and visible P1–P3. Last whorl with adis, IP, P1, P2, P3, s3, P4, P5, P6, s6, t, ADP, MP and ABP. Primary cords giving rise to
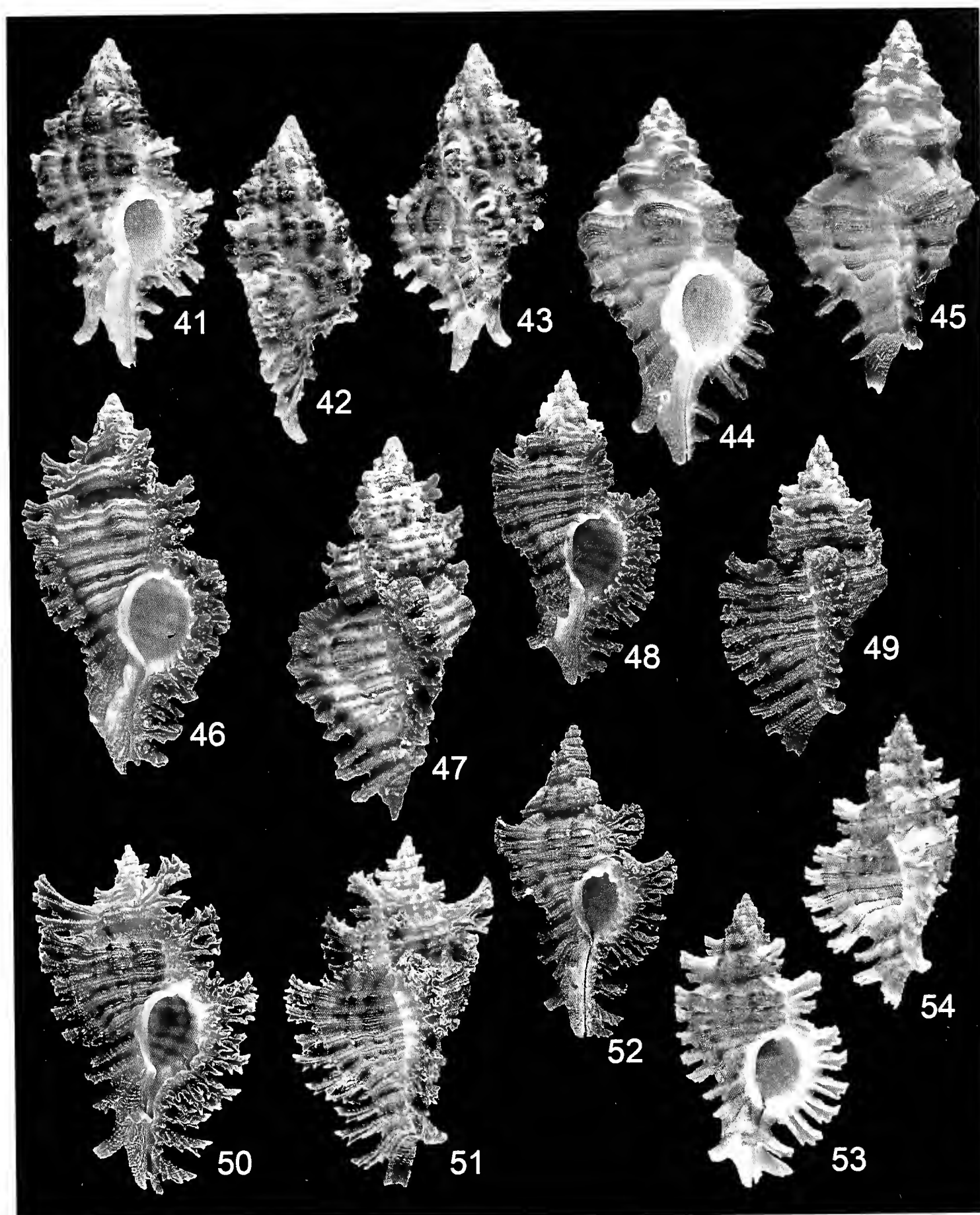
short, frondose spines. P1–P3 of similar strength, P1 with somewhat longer spine; P4 and P5 broader with longer spines; P6 narrow with very short spine. ADP and MP spines short, less frondose than other spines, ABP shallow. Aperture relatively small, roundly ovate. Columellar lip narrow with strong folds abapically and strong parietal tooth at adapical extremity. Rim adherent. Anal notch moderately deep, broad. Outer lip weakly erect, crenulated, with 6 strong, elongate denticles within: ID, D1–D5. Siphonal canal moderately short, 32% of shell length, broad, straight, weakly dorsally recurved at tip, narrowly open, tapered abapically, with 2 short spines extending from ADP and MP. Operculum unknown.

Type Material: Holotype MNHN IM-2000-33593, lv, ad (From type locality.)

Type Locality: Fiji, Viti Levu, Suva area, drop off in 31–40 m.

Distribution: Only known from the holotype, Fiji, Viti Levu, Suva area, living at 31–40 m.

Remarks: *Chicoreus (Triplex) aquilus* new species differs strongly from all known Indo-West Pacific *Triplex* species. However, a few of them have more or less close shell characters and may be compared with the new species. These all have a similar size, a narrow shell with a high spire, a moderately long siphonal canal and a small aperture. The closest species, *C. rubescens* (Broderip, 1833) (Figures 44–45) has a similar aperture, a moderately long siphonal canal and short variceal spines, and occurs in French Polynesia (type locality), Wallis, and New Caledonia. The apertures are strikingly similar, although relatively smaller in *C. aquilus*, both being roundly ovate, glossy white with a narrow columellar lip completely adherent to the shell, bearing a strong, elongate knob abapically, and a strong, broad parietal tooth adapically. The outer apertural lip is crenulated with strong, elongate denticles in both species. The siphonal canal also bears two short, abapically bent spines. However, *C. aquilus* differs from *C. rubescens* by having narrower axial varices with more strongly frondose spines, 2 or 3 intervariceal axial ribs instead of a single, broad rib in *C. rubescens* and less numerous spiral threads. In Houart (1992: 62) *C. rubescens* belongs to "group 2" with *C. microphyllus* (Lamarck, 1816), *C. strigatus* (Reeve, 1849), *C. paini* Houart, 1983 and *C. trivialis* (A. Adams, 1854). Of these species *C. aquilus* new species can only reasonably be compared additionally to *C. strigatus* and *C. paini*. The new species differs from *Chicoreus strigatus* (Figures 46–49) by having less obvious and less frondose variceal spines, more numerous, higher intervariceal ribs, broader primary spiral cords, a more rounded aperture with strong, thick, abapical folds (absent in *C. strigatus*), a stronger parietal tooth and a broader, shallower anal notch. The siphonal canal in *C. aquilus* new species is also straighter with a more tapered shape. *Chicoreus aquilus* new species also differs from *C. paini* (Figures 50–52) by having less obvious and

Figures 41–54. *Chicoreus* species. **41–43. *Chicoreus (Triplex) aquilus* new species.** Holotype, MNHN 1M-2000-33593, Fiji, southern Viti Levu, Suva area, drop off in 31–40 m, 36.5 mm. **44–45.** *Chicoreus (Triplex) rubescens* (Broderip, 1833), RH, locality doubtful, in a collection lot of shells from Tahiti, Marquesas, and New Caledonia, 48 mm. **46–49.** *Chicoreus (Triplex) strigatus* (Reeve, 1849), **46–47.** RH, Japan, Ryukyu Islands, 51.1 mm. **48–49.** RH, Japan, Okinawa, Buckner Bay, under coral, 32.4 mm. **50–52.** *Chicoreus (Triplex) paini* Houart, 1983, **50–51.** RH, Palau, near Koror-Babeldaob bridge, 0.6–1.5 m, among silty rocks, 38.4 mm. **52.** Paratype RH, Solomon Islands, Honiara, 37.6 mm. **53–54.** *Chicoreus (Triplex) dodongi* Houart, 1995. RH, Philippines, Samar, Capul Island, 25 m, 30.6 mm.

frondose variceal spines, a different aperture and a straighter siphonal canal, which is more strongly tapered at the abapical extremity. *Chicoreus dodongi* Houart, 1995 (Figures 53–54) is here added to "group 2" in Houart (1992) and compared with *C. aquilus* new species; the new species differs by having less frondose varices, obviously lower and narrower intervariceal ribs, narrower primary spiral cords and a comparatively longer and more strongly abapically tapered siphonal canal.

Etymology: Latin *aquilus*, dark colored, blackish, naming after the particular and distinctive color of the holotype.

Japanese Name : "*Kurozome-Senju*," クロゾメセンジュ, with "kurozome" meaning "stained in black".

ACKNOWLEDGMENTS

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Bathyacmaea becki, a new species of pectinodontid limpet (Gastropoda: Pectinodontidae) from a hydrothermal vent of the Manus Back-Arc Basin

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ABSTRACT

A new western Pacific species of the deep-sea limpet family Pectinodontidae is described from hydrothermal vents in Manus Back-Arc Basin, at depths of 1714–1853 m. *Bathyacmea becki* new species is most similar by shell morphology to its geographically closest congener *Bathyacmaea jonassoni* Beck, 1996. However, the new species is characterized by a radula with widened functional lateral teeth, which separates it from other congeners. Phylogenetic reconstructions based respectively on partial sequences of COI and 16S rRNA also support its placement within *Bathyacmea*.

Additional Keywords: Patellogastropoda, chemosynthetic environment, radula, deep-sea

INTRODUCTION

The Manus Basin is one of the best known hydrothermal vent areas in the western Pacific, occupying a back-arc position with respect to the New Britain arc-trench system and containing an active plate boundary (Both et al., 1986). To date, the gastropod fauna of this area has been studied by various authors (e.g., Desbruyères and Laubier, 1989; Beck; 1991; 1992a; 1992b; 1993; Bouchet and Warén, 1991; Warén and Bouchet, 1993). During these studies more than a dozen species have been reported (for reviews see Warén and Bouchet, 2001; Sasaki et al., 2010). Pectinodontidae Pilsbry, 1891 is a family of deep-sea limpets inhabiting chemosynthetic environments (*Bathyacmaea* Okutani, Tsuchida and Fujikura, 1992 and *Serradonta* Okutani, Tsuchida and Fujikura, 1992, for review see Sasaki et al., 2010) and sunken wood (*Pectinodonta* Dall, 1882, for review see Marshall, 1985; Marshall et al., 2016). Species of *Bathyacmaea* are restricted to the western Pacific region. The group so far consists of six recognized species, known from the Edison Seamount (Beck, 1996), Sagami Bay of Japan (Okutani et al., 1992), Okinawa Trough

(Okutani et al., 1993; Sasaki et al., 2003), Nankai Trough (Sasaki et al., 2003) and South China Sea (Zhang et al., 2016).

In the present study, we describe one additional species of *Bathyacmaea*, which was collected by ROV Faxian and a Television Grab (based on mother ship R/V Kexue) during a research cruise carried out by Institute of Oceanology, Chinese Academy of Sciences (IOCAS) in 2015. *Bathyacmaea jonassoni* Beck, 1996 from the Edison Seamount represents the geographically closest taxon to the new species.

MATERIALS AND METHODS

A total of 28 specimens (see Table 1) was collected during several dives of the ROV Faxian and Television Grab (IOCAS) from hydrothermal vent fields, the Pacmanus field (Binns and Wheller, 1991) and Desmos cauldron field (Tufar, 1990). For more detailed information about these sites, see Hashimoto et al. (1999) and Fourre et al. (2006). The materials were fixed in 99.5% ethanol immediately after collection.

Light and Scanning Electron Microscopy: The shell and soft parts were observed under light microscopy, and the radulae using a scanning electron microscope (SEM). For SEM studies, radular sacs were removed and placed in a 10% NaOH solution for 4–5 hours. The radulae were then dehydrated through an ethanol series and laid on a cover slip to air-dry. Samples were coated with gold and examined under a Hitachi S-3400N scanning electron microscope. Type materials were deposited at the Marine Biological Museum, Chinese Academy of Sciences (MBMCAS), Qingdao, China.

Molecular Procedures: Three specimens of *Bathyacmaea becki* new species and one specimen of *Bathyacmaea lactea* Zhang, Zhang, and Zhang, 2016 were subjected to molecular analysis. Genomic DNA was extracted with the Column Genomic DNA Isolation Kit (Beijing TIANGEN, China) according to the manufacturer's instructions. DNA were eluted in elution buffer and stored at –20°C until use.

Table 1. Shell measurements (in mm) and ratios of **Bathyacmaea becki** new species.

	Collecting condition	Length (L)	Height (H)	Width (W)	L/H ratio	L/W ratio
Holotype	live	17.9	8.6	15.8	2.1	1.1
Paratypes #1	live	17.3	7.4	14.6	2.3	1.2
Paratypes #2	live	13.8	6.2	10.4	2.2	1.3
Paratypes #3	live	11.7	5.8	8.8	2.0	1.3
Paratypes #4	live	15.0	7.3	12.2	2.1	1.2
Paratypes #5	live	10.2	3.8	8.1	2.7	1.3
Paratypes #6	live	9.7	4.5	7.4	2.2	1.3
Paratypes #7	live	8.9	4.0	6.6	2.2	1.3
Paratypes #8	live	11.1	4.1	8.6	2.7	1.3
Paratypes #9	shell only	15.0	5.8	11.8	2.6	1.3
Paratypes #10	shell only	15.6	6.9	12.9	2.3	1.2
Paratypes #11	shell only	16.1	6.7	13.2	2.4	1.2
Paratypes #12	shell only	15.4	6.8	12.5	2.3	1.2
Paratypes #13	shell only	11.0	4.7	8.0	2.3	1.4
Paratypes #14	live	11.9	5.6	8.5	2.1	1.4
Paratypes #15	live	12.3	5.1	9.4	2.4	1.3
Paratypes #16	live	12.2	5.0	9.2	2.4	1.3
Paratypes #17	live	16.1	7.2	12.0	2.2	1.3
Paratypes #18	live	14.4	5.1	10.9	2.8	1.3
Paratypes #19	live	11.1	4.1	8.4	2.7	1.3
Paratypes #20	live	13.6	5.9	10.6	2.3	1.3
Paratypes #21	live	15.0	5.6	10.4	2.7	1.4
Paratypes #22	live	15.4	6.3	12.9	2.4	1.2
Paratypes #23	live	14.9	5.8	12.5	2.6	1.2
Paratypes #24	live	14.7	5.8	11.6	2.5	1.3
Paratypes #25	live	15.8	6.8	12.2	2.3	1.3
Paratypes #26	live	13.2	5.0	10.9	2.6	1.2
Paratypes #27	live	13.0	5.0	9.8	2.6	1.3

The COI region was amplified by polymerase chain reaction (PCR) using the primers LCO1490 (forward: 5′-GGTCAA CAAATCATAAAGATATTGG-3′) and HCO2198 (reverse: 5′-TTAACTTCAGGGTGACCAAAAAATCA-3′) (Folmer et al., 1994); the 16S rRNA region was amplified using the primers 16Sar (forward: 5′-CGCCTGTTTATCAAAAACAT′) and 16Sbr (reverse: 5′-CCGGTCTGAACTCAGATCACGT-3′) (Palumbi, 1996). PCR reactions were carried out in a total volume of 50 μL, including 1.5 mM MgCl$_2$, 0.2 mM of each dNTPs, 1 μM of both forward and reverse PCR primers, 10×buffer, and 2.5 U Taq DNA polymerase. Thermal cycling was performed under the following conditions: 95°C for 3 m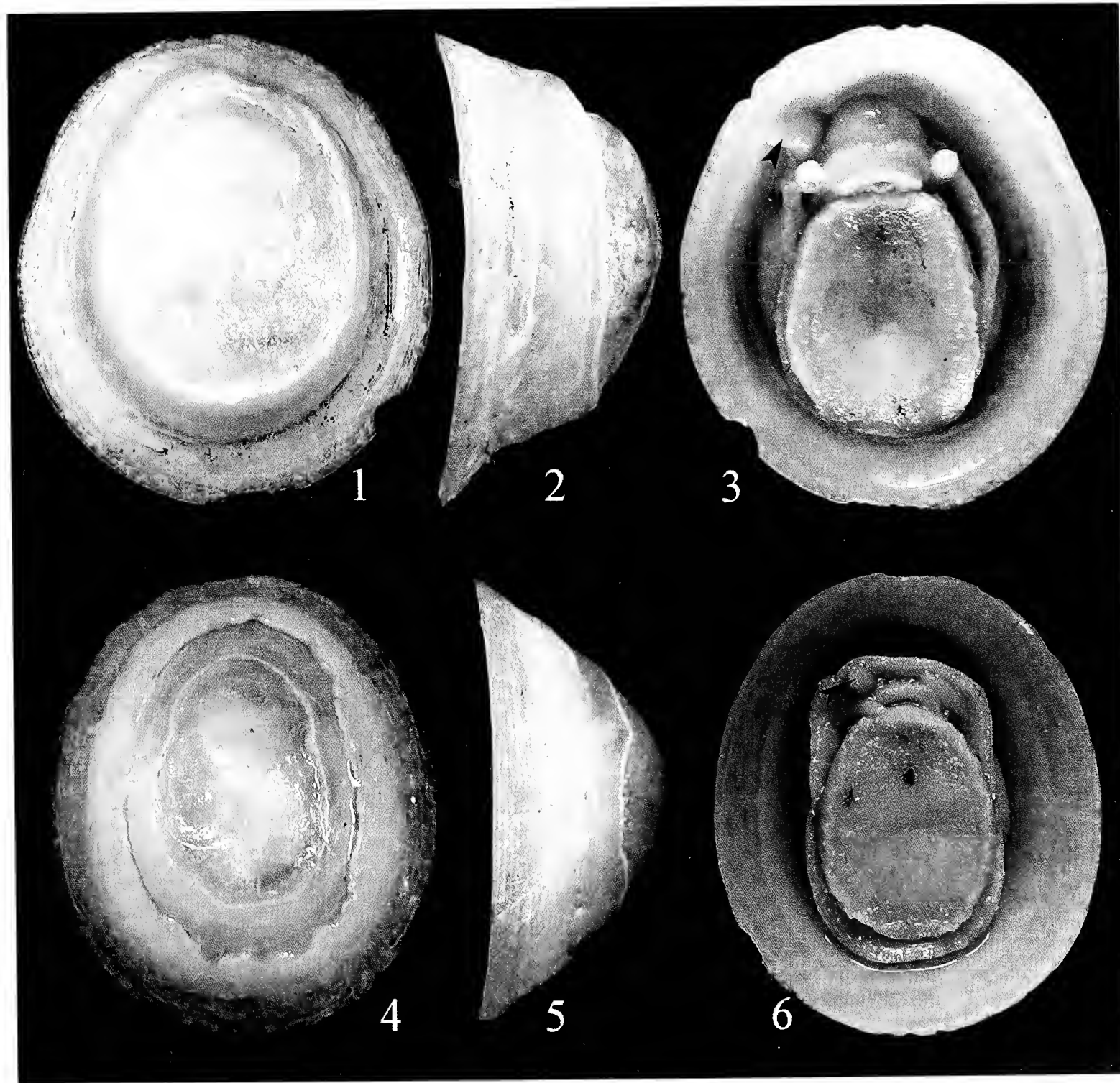in (initial denaturation), followed by 35 cycles of 95°C for 30s (denaturation), annealing temperature for 30s (42°C for COI; 45°C for 16S rRNA), 72°C for 60s (extension), and a final extension at 72°C for 10 min. PCR products were verified by a GelRed-stained 1.5% agarose gel and purified with the Column PCR Product Purification Kit (Shanghai Sangon, China). Purified products were sequenced in both directions. For phylogenetic analyses, COI and 16S rRNA sequences from the present study and those from GenBank were employed (see Table 2, 3). Neighbor-joining (NJ) trees were determined via MEGA 6.06 (Tamura et al., 2013), using Kimura 2-parameter (K2P) model (Kimura, 1980). Bootstrap analyses were performed with 1000 replications.

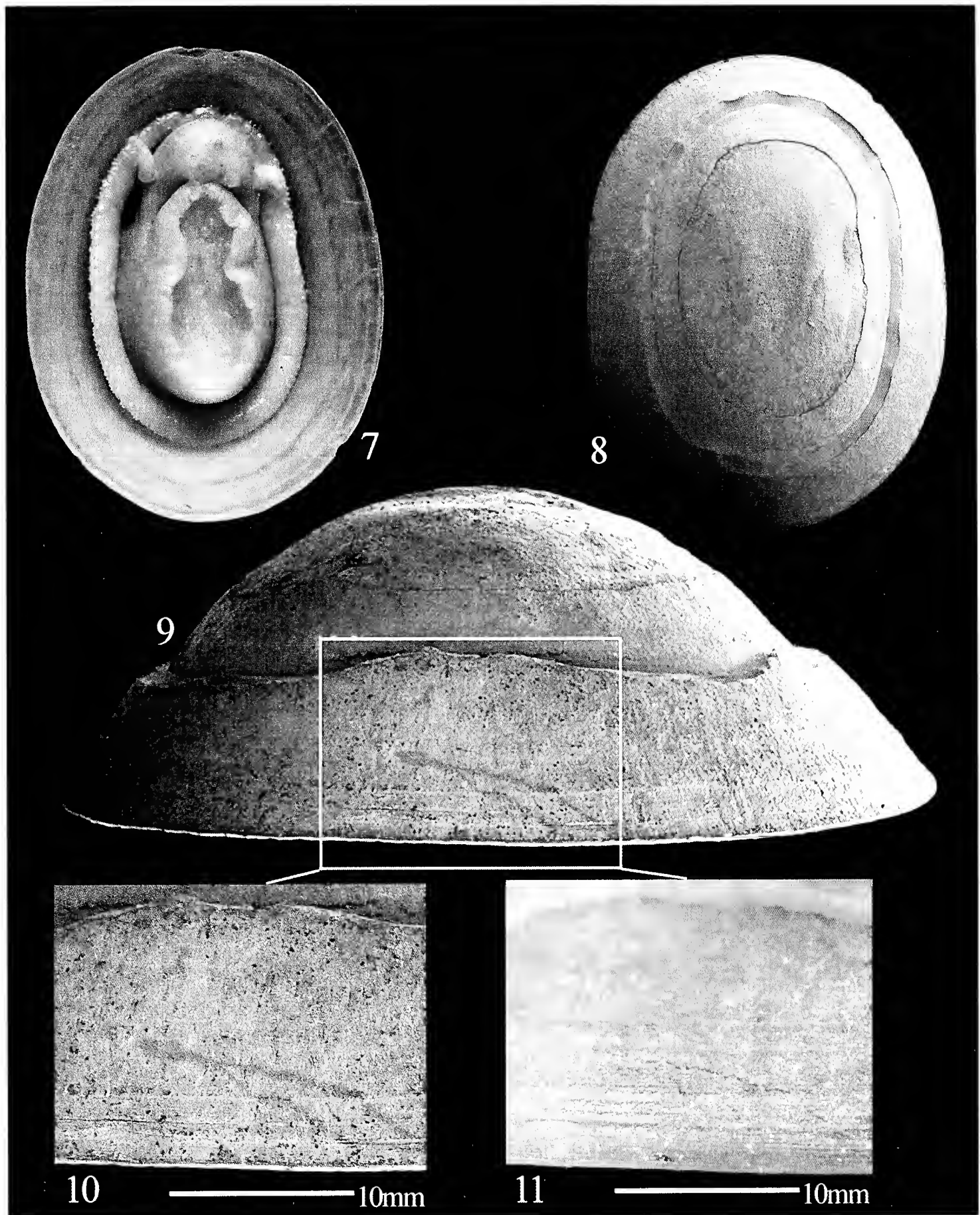Table 2. Works from which the COI sequences derived.

Genus	Species	Accession number	Reference
Bathyacmaea	**Bathyacmaea becki**	MG253685	this study
	Bathyacmaea lactea	MG253686	this study
	Bathyacmaea nipponica	AB238588.1	Nakano and Ozawa, 2007
Pectinodonta	Pectinodonta aupouria	KC990591.1	Marshall et al., 2016
	Pectinodonta marinovichi	KC990594.1	Marshall et al., 2016
	Pectinodonta orientalis	KC970665.1	Marshall et al., 2016
	Pectinodonta rhyssa	AB238589.1	Nakano and Ozawa, 2007
Paralepetopsis (outgroup)	Paralepetopsis sp.	FJ977752.1	Aktipis and Giribet, 2010

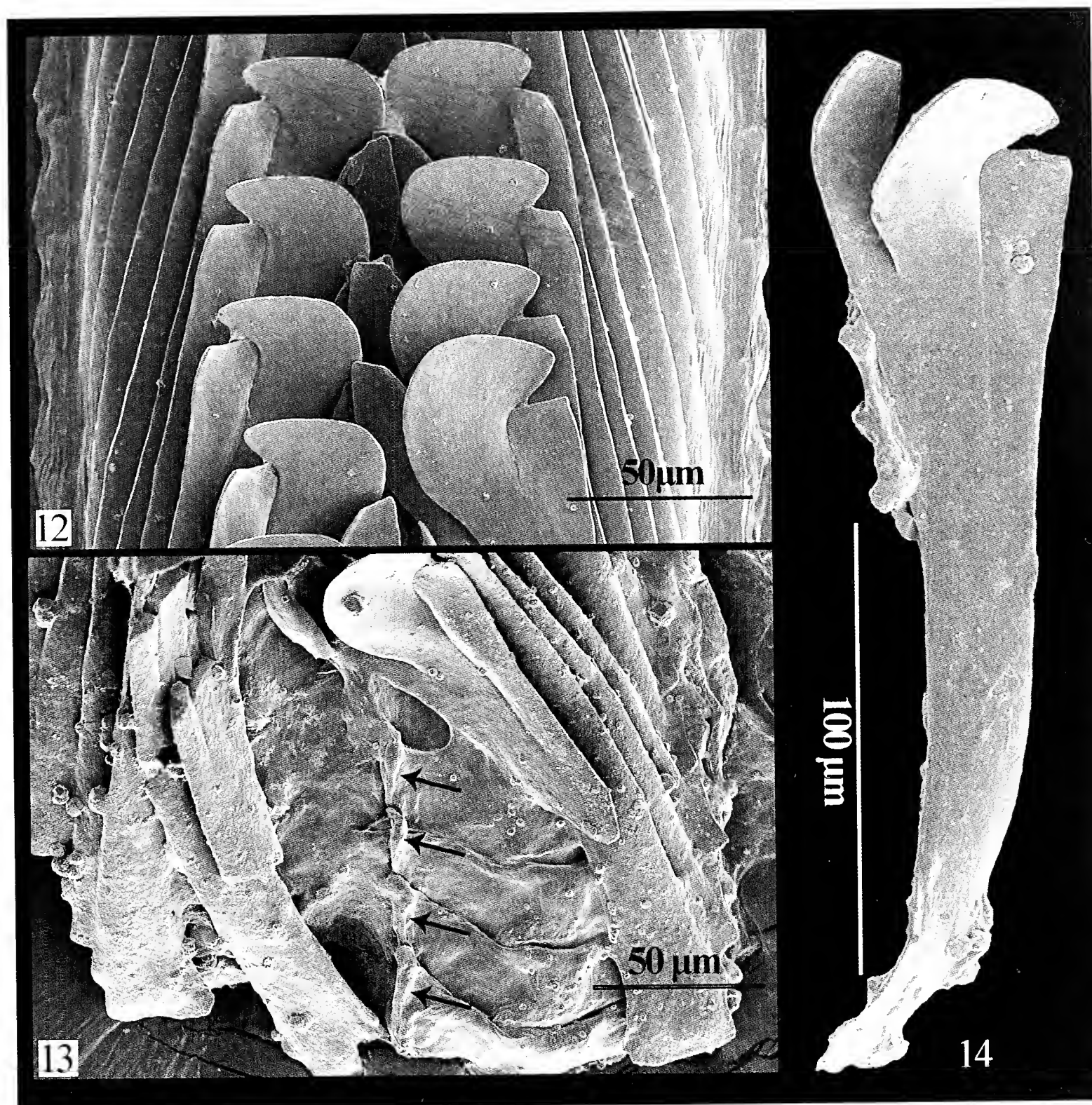**Table 3.** Works from which the 16S rRNA sequences derived.

Genus	Species	Accession number	Reference
Bathyacmaea	**Bathyacmaea becki**	MF499155	this study
	Bathyacmaea lactea	MG265696	this study
	Bathyacmaea nipponica	AB238451.1	Nakano and Ozawa, 2007
Pectinodonta	Pectinodonta rhyssa	AB238452.1	Nakano and Ozawa, 2007
	Pectinodonta sp.	AY163392.1	Warén et al., 2003
	Pectinodonta sp.	AY160667.1	Aktipis and Giribet, 2012
Paralepetopsis (outgroup)	Paralepetopsis sp.	FJ977699.1	Aktipis and Giribet, 2010

Figures 1–6. *Bathyacmaea becki* **new species.** Shells. **1**. Dorsal, **2**. Left lateral, and **3**. Ventral view of the Holotype, 17.9 mm. **4**. Dorsal, **5**. Left lateral, and **6**. Ventral view of Paratype 1, 17.3 mm.

Figures 7–11. *Bathyacmaea becki* **new species. 7.** Ventral view of Paratype 2. **8.** Dorsal and, **9.** Lateral view of Paratype 7. **10.** Shell margin under SEM and, **10.** Under light microscopy, showing microsculpture.

Figures 12–14. *Bathyacmaea becki* **new species.** Radula. **12.** Dorsal view of intact radular segment. **13.** Rachidian region, arrows indicate vestigial rachidian teeth. **14.** Single lateral tooth.

Abbreviations: CN: collection number; 16S rRNA: 16S ribosomal RNA; MBM: Marine Biological Museum; RN: Registration number.

SYSTEMATICS

Family Pectinodontidae Pilsbry, 1891

Genus *Bathyacmaea* Okutani, Tsuchida, and Fujikura, 1992

Type Species: *Bathyacmaea nipponica* Okutani, Tsuchida, and Fujikura, 1992 (off Hatsushima Islet, Sagami Bay, Japan, between depths of 1110–2000 m).

Bathyacmaea becki **new species**
(Figures 1–16)

Diagnosis: Shell whitish, thin, semi-transparent. Shell surface sculptured with obsolete, concentric growth lines, crossed by very faint axial ridges. Aperture oval to nearly

Figure 15. *Bathyacmaea becki* **new species.** Dorsal view of soft parts of Paratype 2, with mantle skirt removed. Abbreviations: **a:** anus; **bct:** bipectinate ctenidium; **ct:** cephalic tentacle; **dg:** digest gland; **ebv:** efferent branchial vein; **gon:** gonad; **in:** intestine; **lk:** left kidney; **n:** neck; **pc:** pericardium; **pm:** pallial margin; **pp:** pallial papillae; **rk:** right kidney; **sm:** shell muscle: **sto**: stomach; **ugp:** urogenital papilla.

rounded in shape, anterior end slightly narrower. Radula formula 0+1+0+1+0, lateral teeth trifurcated, with straight, stout shaft, all three cusps widened, the outermost one with truncated tip.

Description: SHELL (Figures 1–11) patelliform, thin (ca. 0.6 mm above aperture margin in holotype), semi-transparent. Outline oval to nearly rounded, longer than wide, width 71–91% (mean 78%) of the length, anterior end slightly narrower than posterior end. Profile high for genus, height 36–50% (mean 42%) of the shell length. Apex on mid-line slightly anterior to center of shell, moderately eroded, protoconch not preserved. All slopes convex, with prominent constriction at transition to thickened peristoma. External surface whitish, sculptured consisting of concentric growth lines, crossed by very faint axial ridge (Figures 9, 10, 11). Aperture slightly concave at sides; margin thickened, slightly reflected.

SOFT PARTS (Figures 3, 6, 7, 15):

Head rounded, stout. Cephalic tentacles short, tapering. Eyes and oral lappets lacking. Foot sole large, ovate in

shape, anterior pedal gland lacking, no obvious epipodium; mantle edge with numerous papillae, more developed in juveniles (Figure 7). Ctenidium bipectinate, large, usually extending out of the mantle cavity (Figures 3, 6, arrows). Radular sac not very long for a patellogastropod, extending from buccal cavity straight to middle part of visceral mass (at level of stomach), where it turns to right to form large loop. Posterior part of radular sac entirely embedded in digestive gland. Intestine blackish due to dark-gray contents. Stomach moderately large, C-shaped, situated in central position of visceral mass. Intestine and stomach containing soft, lumpish material. Gonad situated posteriorly to visceral mass. Urogenital papilla digitiform, situated right-anteriorly to visceral mass. Pericardium (Figure 15) situated left-anteriorly to corner of visceral mass. Left kidney very small, located to right of pericardium, between basal gill and rectum. Pericardium separated from left kidney, as in some patellogastropods, i.e. Acmaeidae, Lottiidae, and Neolepetopsidae. Right kidney more developed, situated at right anterior corner of visceral mass.

RADULA (Figures 12–14):

Docoglossate with formula 0+1+0+1+0. Lateral tooth trifurcated, with straight, stout shaft. Single lateral tooth ca. 220 μm long. Innermost cusp relatively narrow, with pointed tip; middle cusp spoon-shaped, strongly curved outward; outermost cusp widened, with truncated tip.

Type Locality: Pacmanus hydrothermal vent field, Manus Back-Arc Basin, 3°44′02.329″ S, 151°40′39.419″ E, 1740 m, hard bottom,.

Type Material: Holotype: RN: MBM285093 (length 17.9 mm, width 15.8 mm, height 8.6 mm), CN: M067, Dive 33, 12 June 2015, from type locality; **paratypes 1–3**, RN: MBM285094, CN: M067, collected with the holotype from Fenway vent in Pacmanus field; from type locality; **paratypes 4–8**, RN: MBM285095, CN: M200, collected by Television Grab (TVG) from Fenway vent in Pacmanus field, 3°43.728′ S 151°40.326′ E, 1714 m, hard bottom, 20 June 2015; **paratypes 9–13**, RN: MBM285096, CN: M073, Dive 34, collected from Desmos cauldron field, 3°41′30.352″ S 151°51′56.172″ E, 1921 m, 13 June 2015; **paratypes 14, 15**, RN: MBM285097, CN: M045, Dive 32, collected Satanic Mills vent in Pacmanus field, 3°43′41.660″ S 151°40′09.793″ E, 11 June 2015; **paratype 16**, RN: MBM285098, CN: M022, Dive 31, collected from Desmos cauldron field, 03°43′40.803″ S, 151°40′09.189″ E, 10 June 2015; **paratypes 17–21**, RN: MBM285099, CN: M087, Dive 36, collected from Desmos cauldron field, 03°42′40.206″ S, 151°52′50.368″ E, 14 June 2015; **paratypes 22–27**, RN: MBM285100, CN: M129, Dive 39, collected from Desmos cauldron field, 3°40′54.605″ S, 151°51′47.613″ E, 1853 m, 17 June 2015. All type specimens were
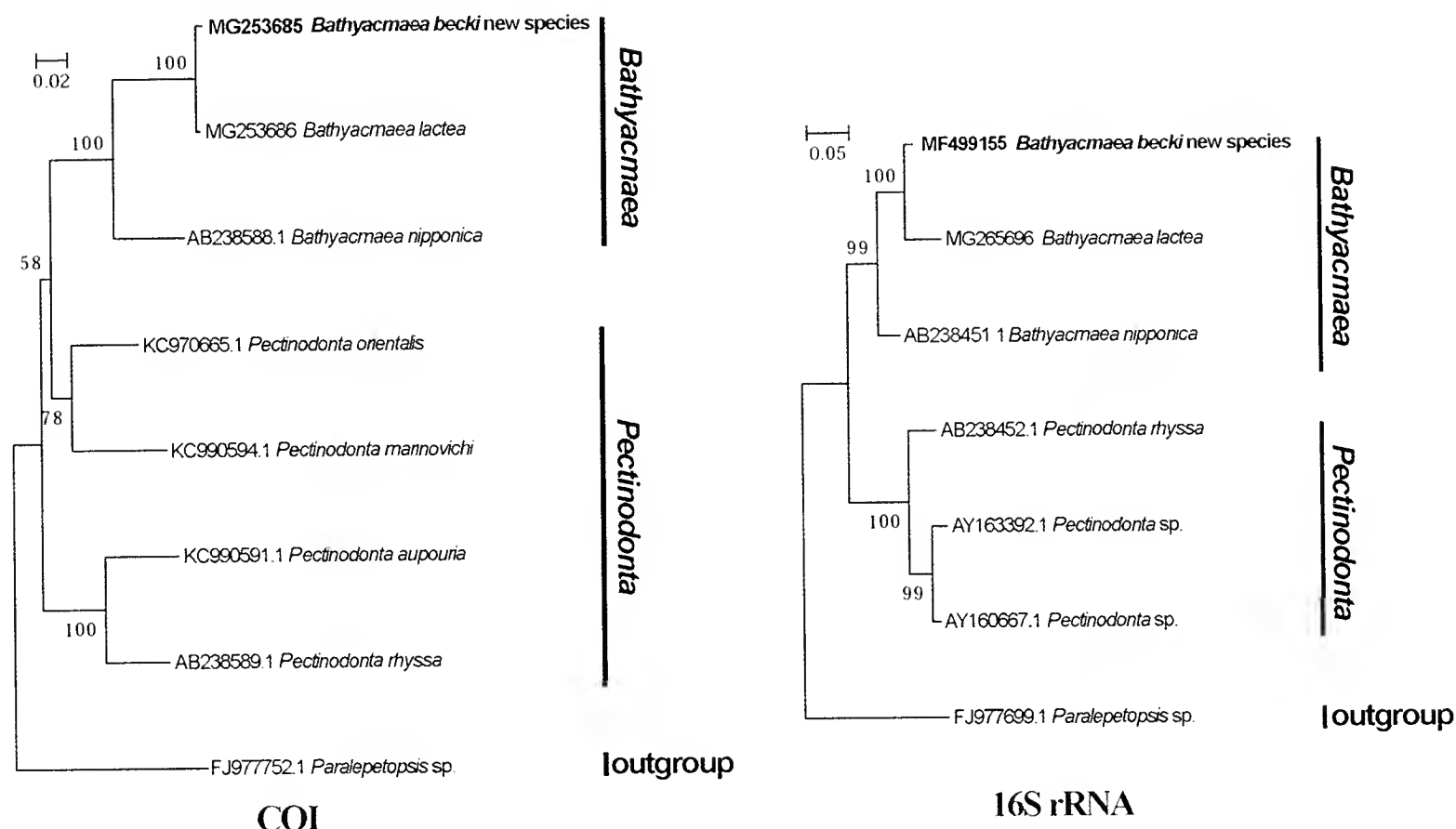
Figure 16. Neighbour-joining trees for Pectinodontidae based on suitable COI and 16S rRNA sequences from GenBank and this study. Numbers above branches indicate the bootstrap values.

collected during the CHINA 1501 Vent Cruise of the R/V Kexue, via ROV Faxian and Television Grab.

Distribution and Habitat: Pacmanus and Desmos cauldron field in the Manus Back-Arc Basin, live on mussels or rock surface, at depths of 1714–1921 m.

Etymology: The new species is named after Dr. Lothar A. Beck, in recognition of his pioneering jobs on the gastropod fauna of hydrothermal vents, especially in the Manus Basin.

Remarks: *Bathyacmaea becki* new species is similar in shell morphology to its geographically closest congener *Bathyacmaea jonassoni* Beck, 1996. However, the new species differs from *B. jonassoni* Beck, 1996 and other congeners by having enlarged lateral teeth with widened cusps of which the outermost one with a truncated tip. In addition, *B. jonassoni* Beck, 1996 has lateral teeth with much longer and thinner shaft. *Bathyacmaea subnipponica* Sasaki, Okutani, and Fujikura, 2003 resembles the new species by its similar radula. However, in *Bathyacmaea subnipponica*, the innermost cusp of the lateral tooth is acute, rather than truncated as in *Bathyacmaea becki*. Moreover, *Bathyacmaea subnipponica* may easily be distinguished from *Bathyacmaea becki* by its shell sculpture with a beaded appearance.

The external anatomy of *Bathyacmaea becki* new species approximates that of *Bathyacmaea jonassoni*

Beck, 1996 and *Bathyacmaea secunda* Okutani, Fujikura, and Sasaki, 1993 (see Sasaki et al., 2006). It remarkably differs from them, however, by the shape of the distal end of the urogenital papilla (digitiform in the new species in contrast to bilobed in *Bathyacmaea jonassoni* and *Bathyacmaea secunda*). In addition, the outline of the soft parts of *Bathyacmaea secunda* is more rounded than that of *Bathyacmaea becki* new species.

Examination of the intestine and stomach contents by microscopy revealed some soft, lumpish mass and black mineral particles; no other fragments or remains were observed. The contents may indicate that the new species could feed on bacterial films grazed off from the rock and mussel surfaces where they attach, as occurs with *Bathyacmaea secunda* (see Sasaki et al., 2006). The enlargement of the lateral teeth may make grazing more effective.

Molecular Analyses: Three partial COI sequences (representing a single haplotype) and one 16S rRNA sequence of the *Bathyacmaea becki*, one COI and one 16S rRNA sequences of *Bathyacmaea lactea* were obtained. The sequences have been deposited in GenBank (see Table 2, 3 for accession numbers). The single sequence type obtained from three individuals of the new species is indicative of a high intraspecific conservation of the COI sequence. The Neighbor-joining (NJ) trees (Figure 16) were reconstructed using suitable COI and 16S rRNA sequences from GenBank and this study. The two NJ trees all show that *Bathyacmaea becki* new

species falls into *Bathyacmaea* in which, together with *Bathyacmaea lactea*, it forms a well-supported sister clade to *Bathyacmaea nipponica* Okutani, Tsuchida, and Fujikura, 1992. With available molecular data, the analysis of a 639-bp fragment of the COI gene resulted in 1% pairwise distance between *Bathyacmaea becki* and *Bathyacmaea lactea*, 10% between *Bathyacmaea becki* and *Bathyacmaea nipponica;* whereas the analysis of a 495-bp fragment of the 16S rRNA gene showed a 5% pairwise distance between *Bathyacmaea becki* and *Bathyacmaea lactea* and 7% between *Bathyacmaea becki* and *Bathyacmaea nipponica.* Although the small pairwise distance of COI sequences seems not to separate *Bathyacmaea becki* and *Bathyacmaea lactea*, the 6% pairwise distance of 16S rRNA sequences is enough to warrant a separation of the two species. Morphologically, the two species are evidently different from each other, as evidenced by characters of both shell and radula.

ACKNOWLEDGMENTS

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Four new Vetigastropoda (Anatomidae, Seguenziidae) from the northeastern Pacific

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ABSTRACT

Four new species of small to minute Vetigastropoda from two families are described: in the Anatomidae, *Anatoma georgii* new species from the intertidal of Alaska, with its radula illustrated; in the Seguenziidae, *Carenzia golikovi* new species, *Asthelys careyi* new species, and *Seguenzia macleani* new species, all from abyssal depth of the northeastern Pacific.

INTRODUCTION

Anatomidae was recently globally revised by Geiger (2012), with subsequent select additions and corrections by Pimenta and Geiger (2015) and Micali and Geiger (2015). The family comprises 83 valid species. There is generally less material available from higher latitudes, which in part explains that new taxa from relatively shallow waters can still be discovered. Thus far, five species are known from the northeastern Pacific: *Anatoma concinna* (A. Adams, 1962), *A. disciformis* (Golikov and Sirenko, 1980), *A. janetae* Geiger, 2006, *A. kelseyi* (Dall, 1905), and *A. lyra* (Berry, 1947).

Seguenziidae is a relatively small family with some 190 valid species listed in the World Register of Marine Species (Bouchet, 2010). It is generally a deep-water group, with relatively little material available. The most significant contributions have been those of Marshall (1983, 1991), Quinn (1983a; 1983b; 1987; 1997), and Poppe et al. (2006). While the group once was considered a deep divergence within archaeogastropods, in the suborder Seguenziina (Salvini-Plawen and Haszprunar, 1987), it is now recognized as a specialized off-shoot within the larger Trochoidea (Kano, 2008; Geiger, 2012). Studies of the northeastern Pacific molluscan fauna have had sporadic contributions by Dall (1908; 1919), Rokop (1972), Quinn (1983a; 1983b), and McLean (1985); the number of valid species is subject to ongoing revisionary work.

The present contribution is part of the ongoing faunal revision of the northeastern Pacific gastropods. The project was initiated by the late James H. McLean (1936–2016), and is continued by D.L. Geiger, L. Groves, and J. Vendetti (editors; see www.nepacific.org).

MATERIALS AND METHODS

Standard methods for scanning electron microscopy (SEM) were used as detailed in Geiger et al. (2007) and Geiger (2012). Terminology for Anatomidae follows Geiger (2012), while no specialized terminology was necessary for Seguenziidae. Unless specified, measurements refer to maximum dimension. Institutional abbreviations used are: LACM: Natural History Museum of Los Angeles County, Los Angeles, California, USA; SBMNH: Santa Barbara Museum of Natural History, California, USA.

SYSTEMATICS

Anatomidae McLean, 1989

Anatoma Woodward, 1859

Type Species: *Anatoma crispata* Fleming, 1828 (subsequent designation Geiger, 2012: 734).

Anatoma georgii new species
(Figures 1–18)

Misidentification: *Anatoma lyra* (Berry, 1947): Geiger, 2012 (in part): fig. 784A (it is *A. georgii* new species).

Description: Shell small (1.36 mm, holotype 1.17 mm), trochiform depressed. Protoconch of 3/4 whorl, no apertural varix, apertural margin slightly sinusoid, flocculent sculpture. Teleoconch I of 2/3 whorl, finest growth lines only. Teleoconch II of up to 1 1/8 whorls. Shoulder slightly convex, with finest growth lines (Figure 12), last 1/8 whorls with about a dozen finest spiral threads. Suture impressed, sutsel about as wide as selenizone. Base biconvex, with distinct ridge at mid point, without constriction below selenizone, same sculpture of finest spiral threads as on shoulder, periumbilical cord

distinct, no funiculus. Umbilicus moderately wide. Aperture subquadratic. Selenizone at periphery, rather narrow for genus, keels low, slit open with parallel margins.

Animal with eyes. Radula rhipidoglossate, radular interlock moderate (Figures 14–15). Rachidian tooth triangular, cusp with central denticle largest, 4–5 smaller ones on each side (Figure 15). Lateral teeth 1–4 similar, cusp with 3–4 denticles, apicalmost largest (Figure 15). Lateral tooth 5 enlarged, approximately six denticles along inner edge of cusp, 2–3 along outer edge (Figure 16). Marginal teeth without food groove (Figure 17); inner marginal teeth with triangular cusp with 2–4 denticles on each side; outer marginal teeth with spoon-shaped cusp, many fine denticles (Figure 18).

Type Material: **Holotype** SBMNH 472248, dry shell with animal; **paratypes** SBMNH 469832 (1, in 70% ethanol, probably formalin fixed), SBMNH 469836 (1 in 70% ethanol, probably formalin fixed, 2 dry, radula on stub), SBMNH 469837 (2 in 70% ethanol, probably formalin fixed). All from type locality.

Type Locality: Hawk Inlet, Sakagway-Hoonah-Angoon County, Alaska, USA, 58.1237° N, 134.7553° W, intertidal.

Etymology: Named for naturalist and *viola d'amore* virtuoso, scholar, and teacher Thomas (Tom) Georgi for his masterful and nuanced interpretation of early music, particularly his tasteful gestures and ornamentation (Georgi, 2000; 2006; 2007; 2008), and for generously sharing his wealth of knowledge with players around the world, including the author.

Distribution: Alaska mainland to Aleutian Islands, USA.

Remarks: The northeastern Pacific *Anatoma* species differ from *A. georgii* as follows. *Anatoma concinna* has an overall globular shape (not lenticular) and has strong axial and spiral cords on shoulder and base. *Anatoma disciformis* shares the lenticular overall shape, but has distinct axial and spiral sculpture on shoulder and base of the teleoconch. *Anatoma janetae* grows much larger (3.8 mm); the early teleoconch has distinct axial cords in conjunction with the finer spiral lines. *Anatoma keenae* is overall more turreted, and has strong axial and spiral cords on shoulder and base. *Anatoma lyra* is proportionally taller and has axial sculpture of variable strength and a spiral cord in the position of the selenizone.

One specimen illustrated by Geiger (2012: fig. 784A) as a small specimen of *A. lyra* in fact is *A. georgii*. The specimen was also collected in very shallow water (7 m) on Attu Island, Alaska (LACM 79-71). It is a further example that multiple specimens of a new species help in its recognition. Early whorls of true *A. lyra* all have distinct axial sculpture, have a spiral cord in the position of the selenizone, and also have a proportionally wider selenizone. Accordingly, specimens of the new species are not juveniles of *A. lyra*, but the previously figured specimen was not recognized as being distinct.

Most *Anatoma* species are found between 100–1000 m depth; only a few are known from very shallow, and even intertidal waters, such as *A. parageia* Geiger and Sasaki, 2009, from southern Japan. Both species are among the smaller members of the genus *Anatoma*.

Other species with some shallow water records (<5 m/all records) include *A. amydra* Geiger and Marshall, 2012 (1/135 records), *A. aspera* (Philippi, 1844) (4/273 records), *A. conica* (d'Orbigny, 1841) (1/25 records), *A. crispata* (Fleming, 1828) (2/145 records), *A. flemingi* (Marshall, 2002) (1/32 records), *A. janusa* Geiger, 2012 (4/10 records), *A. orbiculata* Geiger, 2012 (1/3 records), *A. philippinica* (Bandel, 1998) (2/47 records), *A. pseudoequatoria* (Kay, 1979) (5/76 records), and *A. rapaensis* Geiger, 2008 (1/62 records). For those species with low frequency of shallow water occurrences, the records are rather an indication of post-mortem transport rather than extensive bathymetric range. The true bathymetric occurrence of the above species is impossible to determine based on empty shells alone. The frequency of records given above is taken as an uncertain proxy to the true range.

The illustrated shells still have some sediment attached to them. Because all material had been stored in fluid, it is extraordinarily fragile. The customary cleaning in an ultrasonic bath would most likely have shattered the specimens. Accordingly, the specimens were not further cleaned. Fortunately, all characters are sufficiently clear to permit an unambiguous assessment. Note that the aperture appears detached in the illustrated paratypes (Figure 5–11), and the sutsel appears wider than the width of the selenizone, contrary to the description. Those apparent discrepancies are artifacts due to the broken nature of the paratypes, as seen in the apical views.

The radula has no special attributes. It is the most common configuration in Anatomidae; see Geiger (2012) for extensive illustrations.
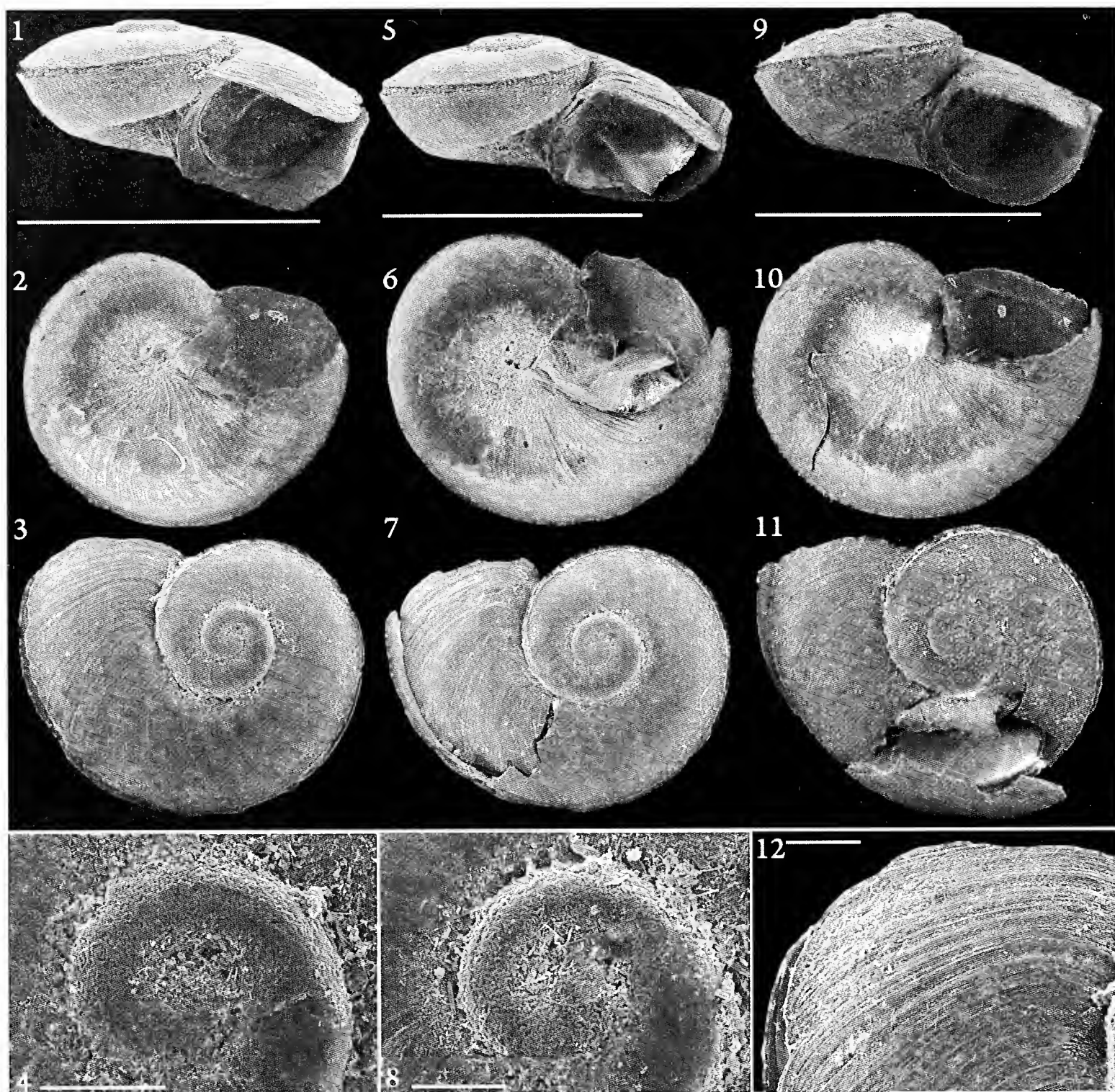
Seguenziidae Verrill, 1884

Remarks: The subfamilies and tribes introduced by Marshall (1991) lack unique diagnostic characters, and the cited character states vary widely within the taxa and overlap significantly among taxa. Marshall (1991: 46) noted the gradual changes amongst character states, and indicated that his tribes should rather be viewed as "informal groupings". The acceptance of a higher taxon by other authors does not mitigate the underlying issue of overlapping character states. Accordingly, none of those names are used here. A multivariate morphospace or phylogenetic analysis may clarify the validity of those higher taxa. The most detailed phylogenetic analysis only contains four seguenziids (Kano, 2008).

Carenzia **Quinn, 1983**

Type Species: *Seguenzia carinata* Jeffreys, 1877 (original designation).

Description: Shell conical, smooth, periphery carinate, mid-whorl carination more or less distinct; base convex, umbilicus narrow; apertural sinuses at periphery and base indistinct.

Figures 1–12. Shells of *Anatoma georgii* new species. 1–4. Holotype SBMNH 473348. 5–11. Paratypes SBMNH 472236. Hawk Inlet, Sakagway-Hoonah-Angoon County, Alaska, USA, 58.1237 ° N, 134.7553° W, intertidal. Scale bars: shells = 1 mm; protoconch = 100 μm. 12. Enlargement of apertural margin of holotype showing finest spiral threads. Scale bar = 100 μm.

Carenzia golikovi new species
(Figures 19–22)

Description: Shell to 5 mm, trochiform; whorls five, rounded; carination on mid shoulder; base convex, good dozen irregularly spaced, spiral lines of variable strength; aperture subquadratic, umbilicus narrow, with indistinct funiculus; axial growth lines indistinct.

Type Material: Holotype LACM 3317, Oregon State University, R/V Wecoma (BMT 535), 19 August 1976; **paratypes** (2) LACM 3318, 5100 m, Aleutian Trench (near western end of chain), 52°12′ N, 175°44′ E, Roman Egorov, via Roger Clark and Ross Mayhew.

Type Locality: Abyssal plain W of Oregon, S of Gulf of Alaska, 5180 m, 45°00′ N, 153°47.7′ W to 45°02.3′ N, 153°55.9′ W.

Distribution: Aleutian Trench, 52° N, 176° W, to S Gulf of Alaska, 45° N, 154° W, 5100 m.

Etymology: Named for Russian malacologist Aleksandr Nikolaevich Golikov (1931–2010).

Figures 13–18. Radula of *Anatoma georgii* new species. **13.** Entire radula. **14.** Full width of radula. **15.** Central field enlarged. **16.** Lateral tooth 5 and marginal teeth. **17.** Cusps of marginal teeth. **18.** Outermost marginal teeth. Scale bars: Figures 13–14 = 100 μm; Figures 15–18 = 10 μm.

Remarks: The overall shell morphology and the thin nacreous lining of the shell suggests placement in Seguenziidae. The closest genus is *Carenzia*, with the absence of strong axial sculpture and the spiral keels at the periphery and on the shoulder of the shell. In *C. golikovi*, however, only the keel on the mid-shoulder is present, while the keel at the periphery is not visible. It is notable that the spiral sculpture on the base starts right at the periphery, for which reason one could consider the uppermost spiral a reduced peripheral keel.

The most similar species in the northeastern Pacific include *C. inermis* Quinn, 1983, with a more basal carination and more inflated whorls. *Carenzia nitens* Marshall, 1991 from New Caledonia shares the smooth surface of the whorls, which, however, are biangulated.

Asthelys Quinn, 1987

Type Species: *Basilissa munda* Watson, 1879 (original designation).

Description: Shell small, biconical, bicarinate whorls macroscopically smooth, aperture trapezoidal.

Asthelys careyi new species
(Figures 23–24)

Description: To 7 mm, white; whorls five, smooth, slightly inflated; suture weakly impressed, base convex, smooth; basal angulation slightly projecting, with small channel above, resulting in weakly bicarinate configuration; aperture trapezoidal, umbilicus represented by narrow chink; bordered by narrowed columellar wall.

Type Material: Holotype LACM 3320, Oregon State University, R/V Wecoma (BMT 535), 19 August 1976.

Type Locality: Abyssal plain W of Oregon, S of Gulf of Alaska, 5180 m, 45° 00′ N, 153° 47.7′ W to 45° 02.3′ N, 153° 55.9′ W.

Distribution: Only known from holotype.

Etymology: Named for Professor Andrew Carey of Oregon State University, Corvallis.
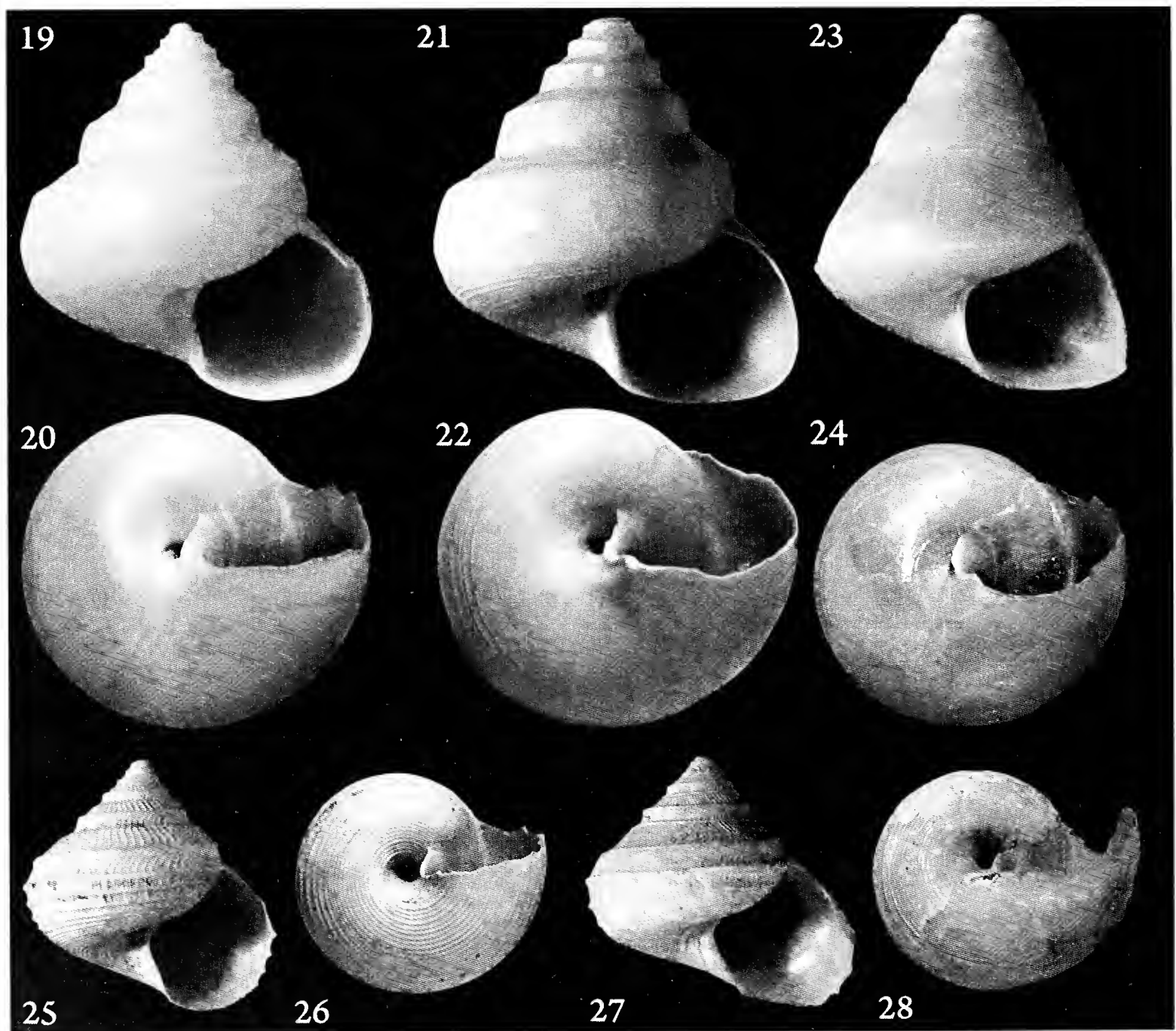
Remarks: The species is placed in the genus *Asthelys* for its conical overall shape and the diagnostic biangulate whorls (Quinn, 1987). That biangulation, though, is very subtle in *A. careyi*, amounting to not much more than a pair of parallel spiral ridges. It is the first representative of the genus from the northern Pacific. The other congeners are known from the Atlantic Ocean and New Caledonia.

The most similar species in the northeastern Pacific is *Carenzia inermis* (Quinn, 1983), which has a more trochiform overall shell shape, more inflated whorls, a rounded aperture, and a narrow yet distinct umbilicus.

Seguenzia Jeffreys, 1876

Type Species: *Seguenzia formosa* Jeffreys, 1876 (monotypy).

Description: Shell to 10 mm, thin, fragile, umbilicate or anomphalous, external and internal surfaces with nacreous luster. Apertural lip bordering the three labral sinuses often flaring in mature shells. Columella curved, ending abruptly. Sculpture of narrow spiral carinae and basal cords, fine spiral threads and sharp axial riblets curving parallel to the labral sinuses.

Figures 19–28. New species of Seguenziidae. **19–22.** *Carenzia golikovi* new species. **19–20.** Holotype LACM 3317, abyssal plain W of Oregon, S of Gulf of Alaska, 5180 m, approximately 45° N, 153.8° W, height 5.3 mm. **21–22.** Paratypes LACM 3318, Aleutian Trench (near western end of chain), 5100 m, 52°12′ N, 175°44′ E. **23–24.** *Asthelys careyi* new species. Holotype LACM 3320, abyssal plain W of Oregon, S of Gulf of Alaska, 5180 m, approximately 45° N, 153.8° W, height = 7.0 mm. **25–28.** *Seguenzia macleani* new species. **25–26.** Holotype, LACM 3321, Aleutian Trench, 5100 m, 175° 44′ E, ~55° 30′ N, height = 8.7 mm. **27–28.** Paratype LACM 3486, abyssal plain W of Oregon, S of Gulf of Alaska, approximately 45° N, 153.8° W, height = 9.6 mm. Photos by James H. McLean.

Seguenzia macleani new species
(Figures 25–28)

Description: Shell 9.6 mm (holotype), 8.7 mm (paratype), trochiform; whorls four, inflated, suture little impressed; spiral cords decreasing in strength from shoulder to base, one on shoulder, one at suture, approximately a dozen on base with stronger spirals randomly interspersed amongst the fine ones; crossed by axial lines decreasing in strength from suture to umbilicus: fewer stronger ones (holotype) or more numerous finer ones (paratype); aperture rounded; umbilicus wide, no funiculus; columella not thickened.

Type Material: **Holotype** LACM 3321 (Figs 25–26), Roman Egorov, via Roger Clark and Ross Mayhew; **paratype** LACM 3485 from type locality; **paratype** LACM 3486 (Figures 27–28), abyssal plain W of Oregon, S of Gulf of Alaska, 5180 m, 45° 00′ N, 153° 47.7′ W to 45° 02.3′ N, 153° 55.9′ W, Oregon State University, R/V WECOMA (BMT 535), 19 August 1976.

Type Locality: Aleutian Trench (near western end of chain), 5100 m, 175° 44′ E, ~55° 30′ N.

Distribution: Abyssal plain off Alaska and Oregon, 45° N, 5100–5180 m.

Etymology: The species honors James H. McLean, who first recognized this new species.

Remarks: The most similar species is *S. cerveola* Dall, 1919, which differs from *S. macleani* by the thickened columella and the columellar chink partially covering the umbilicus. This distinction cannot be explained by size, because the larger *S. macleani* lacks the thickening. Additionally, the spiral sculpture is stronger in *S. cerveola*.

DISCUSSION

The present contribution adds additional taxa of micromollusks to the northeastern Pacific malacofauna. The diversity of Anatomidae, now with six recognized species, is at the lower end in relation to those of other temperate regions. Difficulty to reach the deep-water habitats of most Seguenziidae makes an assessment of their true diversity very challenging, because of limited availability of samples from >200 m, with abyssal plain habits being particularly understudied. The less than one dozen species diversity in the northeastern Pacific is similar to that of six species known from Japan (Okutani, 2017).

The specimens of *A. georgii* were found in voucher material from an ecological study deposited at SBMNH and identified as "*Scissurella* sp." This is an instance that confirms the paradigm that new fieldwork is not necessarily required for the discovery of new taxa. The backlog of unprocessed material in natural history collections represents a highly valuable and readily accessible source for additional material. Given the ever more restrictive permitting requirements and import-export complications,

working up backlog material is an excellent and cost-effective strategy for discovering new taxa.

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First Cretaceous record of the gastropod *Exilia* (Neogastropoda: Ptychatractidae) from the northeastern Pacific

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ABSTRACT

A new species of the ptychatractid neogastropod, ***Exilia stechesonae* Squires**, is described from Upper Cretaceous (upper lower to lower upper Campanian) strata in southern California. It is found predominantly in the lower and middle parts of the Chatsworth Formation in the Simi Hills, Los Angeles and Ventura counties, and in the Pleasants Sandstone Member of the Williams Formation in the Santa Ana Mountains, Orange County. Specimens lived at shelfal depths and were subject to post-mortem transport into deeper waters. The new species is first Cretaceous record of *Exilia* Conrad, 1860 in the northeast Pacific.

Additional Keywords: Dayton Canyon, Bee Canyon, *Paleofusimitra*

INTRODUCTION

Neogastropods, which are among the geologically youngest of all the gastropod groups, first appeared in the Cretaceous. Their increasing diversity, especially during the Late Cretaceous, is one of the major features of gastropod evolution (Sohl, 1987; Harasewych et al., 1997). According to Kantor (2002), one of the most primitive of the neogastropods is family Ptychatractidae Stimpson, 1865, whose fossil record is based predominantly on *Exilia* Conrad, 1860. The geologic range of *Exilia* is Late Cretaceous (Coniacian) to Holocene (Kantor et al., 2001). During the Maastrichtian, *Exilia* became more widespread globally, and this expansion continued into the early Cenozoic. Several Paleocene, Eocene, and early Oligocene *Exilia* species are present in the northeast Pacific (Bentson, 1940; Squires, 2003).

This present study concerns the recognition of a new species, ***Exilia stechesonae* Squires**, from shallow-marine Upper Cretaceous (Campanian) beds in the Chatsworth

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and Williams formations in southern California (Figure 1). It is the first Cretaceous occurrence of *Exilia* in the northeast Pacific region. Additional significance of the new species is that is helps to better understand the early evolution of *Exilia*. **The senior author, Squires, is the sole author of this new species.**

MATERIALS AND METHODS

The new species is based on 40 specimens stored in the Invertebrate Paleontology Collection of the Natural History Museum of Los Angeles County. Details about the localities of the new species are given in Appendix 1. Cleaning of apertures and cutting of a few longitudinal cross sections were done mostly by others using a hand-held, high-speed drill with diamond-coated drilling wheels. The classification system of Bouchet (2014) is followed here, but the "subclass" and "order" categories remain in a state of flux. Morphologic terms are from Cox (1960a).

Abbreviations used in the text are: CIT: California Institute of Technology, Pasadena (collection now stored at LACMIP); CSUN: California State University, Northridge (collection now stored at LACMIP); LACMIP: Natural History Museum of Los Angeles County, Invertebrate Paleontology; UCLA: University of California at Los Angeles (collection now stored at LACMIP); VIPM: Vancouver Island Paleontological Museum, Qualicum Beach, British Columbia, Canada.

STRATIGRAPHY, DEPOSITIONAL ENVIRONMENTS, AND AGES

The geology and paleontology of the Chatsworth Formation are discussed in Squires et al. (1981), Link et al. (1984), and Stecheson (2004). Inventories of the molluscan fossils in this formation are in Popenoe (1942) and
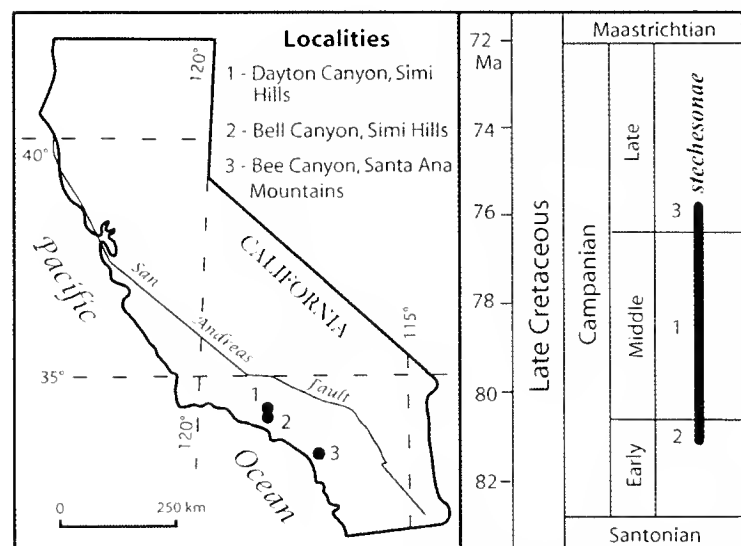
Figure 1. Index map and chronostratigraphic diagram. Geologic ages from Gradstein et al. (2012).

Saul and Alderson (1981). Stecheson's (2004) study was the first comprehensive systematic paleontologic study done on the gastropods of the Chatsworth Formation in the Bell Canyon and Dayton Canyon areas in the southeastern part of the Simi Hills (Fig. 1). Faulting and discontinuous bedding obscure the stratigraphic relationships between the Bell Canyon and Dayton Canyon fossil localities, but the Bell Canyon beds are slightly older than the Dayton Canyon beds (Stecheson, 2004). The base of the Chatsworth Formation is not exposed (Link et al., 1984).

Only a few specimens of the new gastropod were found at LACMIP loc. 10710 in the lower 10 m of the lower part of the stratigraphic section of the Chatsworth Formation exposed in Bell Canyon. The fossils at this locality are concentrated in lens-shaped beds of calcareous sandstone that accumulated as channelized deposits in slope and submarine mid-fan facies (Link et al., 1984). Based on the concurrent ranges of the gastropods *Volutoderma averillii* and *Lysis suciensis*, the rocks at this locality are of late early Campanian age (Saul and Squires, 2008a, 2008b).

Nearly all of the fossils of the new species were found at its type locality (LACMIP loc. 10715). This locality, which is in the middle part of the Chatsworth Formation in Dayton Canyon, Los Angeles County, southern California, is approximately 4 km northeast of Bell Canyon. Locality 10715 was described by Squires and Saul (1981) as a 1.8 m thick and 15 m long, highly fossiliferous lens. Fossils make up about 80 percent of the lens. In addition to gastropods, there are bivalves, ammonites, nautiloids, and shark teeth. The fossils were likely swept from various depths on a shelf by channelized debris flows, then transported and concentrated on the adjacent slope (Link, 1981; Link et al., 1984). The rock type at the locality is fine- to medium-grained sandstone with scattered rip-up clasts. The poorly sorted fossil remains are stratified. Although most of the fossils are fragmental, they are not worn or abraded (Squires and Saul, 1981). Based on the presence of the gastropods *Volutoderma angelica*, *V. blakei*, *V. santana*, and *V. elderi*, the rocks at this locality are of middle Campanian age (Saul and Squires, 2008a).

Nearly all the specimens from the Williams Formation are poorly preserved fragments, except for a specimen (Fig. 8) found at LACMIP loc. 42320 near the mouth of Bee Canyon, southern California (Fig. 1). This locality is in a fault-bounded inlier of Upper Cretaceous rocks mapped by Schoellhamer et al. (1981) and referred to by Saul and Squires (2008a) as the Pleasants Sandstone Member. These rocks are shallow-marine shelfal deposits containing the gastropod *Volutoderma? antherana*, which is indicative of early late Campanian age (Saul and Squires, 2008a).

During the Campanian, the west coast of the United States was part of the "Northeast Pacific Subprovince" of Kauffman (1973: fig. 1), which, in turn, was part of his "North Temperate Realm." This subprovince had warm-temperate coastal conditions (Kiel, 2002: fig. 2; Saul and Squires, 2008a).

SYSTEMATIC PALEONTOLOGY

Class Gastropoda Cuvier, 1797
"Subclass" Caenogastropoda Cox, 1960b
"Order" Neogastropoda Wenz, 1938
Superfamily Turbinelloidea Rafinesque, 1815
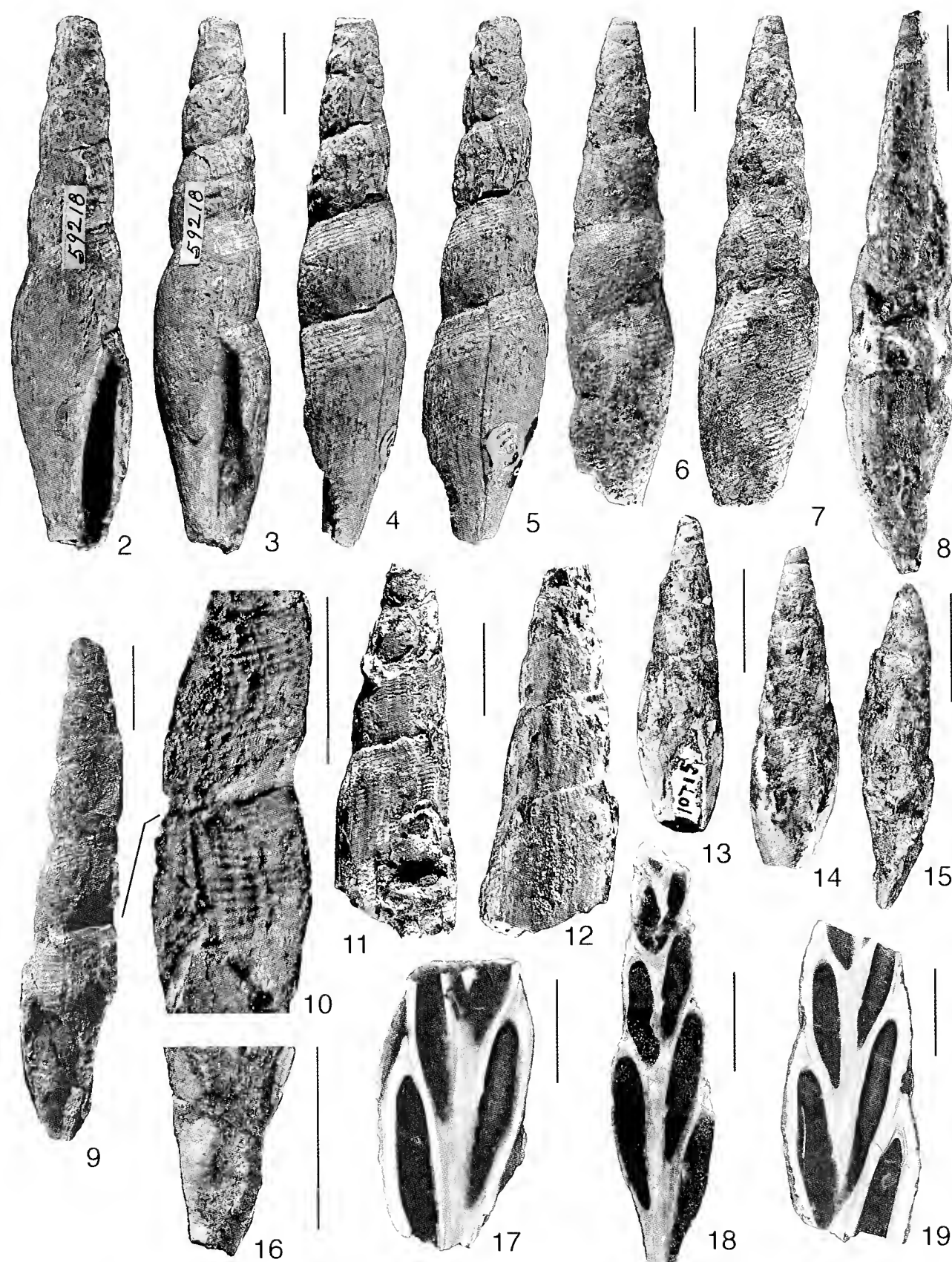Family Pytchatractidae Stimpson, 1865
[= Graphidulidae Stephenson, 1941]

Discussion: Stimpson (1865: 59) named the family Ptychatractidae to accommodate his new genus *Ptychatractus*, a deep water modern-day gastropod from Maine and Nova Scotia. He did not comment on the higher taxonomic relationships of his family, which has an ongoing unsettled and inconsistent classification history. Nielsen (2005) provided a succinct discussion of this complicated history. Kantor et al. (2001) discussed the synonymy of genus *Exilia* in detail. Classification adjustments continue to modern day, as evidenced by recent anatomical and molecular phylogeny studies done by Fedosov et al. (2017), which indicate close relationships among modern costellariids (ribbed miters), ptychatractids, and volutomitrids.

Genus *Exilia* Conrad, 1860

Type Species: *Exilia pergracilis* Conrad (1860, by monotypy; middle Paleocene ["Midway"]), Alabama, Mississippi, and Texas (Palmer and Brann, 1966; Toulmin, 1977).

Description: Shell approximately 10 to 101 mm height; most shells 15 to 55 mm height. Height/width ratio ranges from 3.2 to 5.3. Fusiform, long and narrow to moderately short and moderately wide. Spire high to, less commonly, short. On unbroken specimens, height of spire commonly greater than height of aperture. Spire outline evenly tapered or knobby/angulate. Spire (pleural) angle 13° to approximately 30°. Protoconch smooth, 0.8 to 3 whorls (paucispiral or multispiral), depending on larval development. Teleoconch with up to approximately eight or nine

Figures 2–19. *Exilia stechesonae* new species Squires, LACMIP loc. I0715, southern California, Chatsworth Formation, unless otherwise indicated. **2–5.** Holotype LACMIP I0496. **2.** Apertural view. **3.** Apertural view, turned slightly to show columella interior. **4.** Right-lateral view. **5.** Abapertural view, showing growth line. **6–7.** Paratype LACMIP I4748. **6.** Right-lateral view. **7.** Abapertural view. **8.** Paratype LACMIP 14749, right-lateral view. **9–10.** Paratype LACMIP I4750, LACMIP loc. 42320, Pleasants Sandstone Member. **9.** Abapertural? view. **10.** Closeup of two whorls; crooked line denotes same juncture of two whorls in previous figure. **11–12.** Paratype LACMIP 1475I, upper spire. **11.** Apertural view. **12.** Abapertural view. **13–14.** Paratype 14752. **13.** Apertural view. **14.** Abapertural view. **15.** Paratype 14753, LACMIP loc. I07I0, left-lateral view showing upturned anterior end. **16.** Paratype LACMIP 14754, apertural view of anterior end. **17.** Paratype LACMIP 14755, longitudinal view of interior showing I–2 plaits. **18.** Paratype LACMIP 14756, longitudinal view of interior showing 1–2 plaits. **19.** Paratype LACMIP 14757, longitudinal view of interior showing 1–2 plaits. Scale bars = 10 mm.

whorls, or, much less commonly, four to five whorls. Whorls convex (rarely somewhat flat-sided), with convexity weak to moderately strong; whorls can be angulate (rarely tabulate). Sculpture varies considerably in strength, from very weak to strong. Most shells with obvious sculpture (especially on spire), whereas some shells overall smooth-looking. Axial ribs weak to strong and commonly stronger than spiral sculpture. Axial ribs narrow to moderately wide in size and spacing; straight or curved, commonly elongate and extending from suture to suture, but not aligned with axial ribs on adjacent whorls. Axial ribs can be noded. Axial ribs common on spire and most of last whorl; or axial ribs only on upper spire. Spiral ribs very weak to strong, narrow to moderately wide, commonly closely spaced. Spiral ribs strongest on shoulder and neck but can be nearly obsolete on shoulder of last whorl. Cancellate sculpture moderately common. Aperture narrow to moderately wide, narrowly elongate. No anal sulcus. Outer lip thin and smooth. Columella callus slight, with zero or two to four concealed plaits of variable strength. Siphonal canal commonly long but can be relatively short (attenuated). Siphonal notch narrow to moderately narrow. Anterior end very rarely upturned slightly but untwisted (i.e., no siphonal fasciole). Operculum absent, or very small with subcentral nucleus, or medium sized with terminal nucleus. Growth line straight or inclined on spire whorls; slightly sinuous on last whorl, with deflections near suture, on angulation at periphery, and on neck (Bentson, 1940; Kantor et al. 2001; herein).

Geologic Age: Coniacian to Holocene (Kantor et al., 2001: fig. 5).

Discussion: *Exilia* has considerable variation in its spire angle, height/width ratio, morphology of the protoconch, relative strengths of the spiral and axial sculpture, and number and strength of the columellar plaits (Kantor et al., 2001: 84). To this list, we add shell size, spire height, and aperture width. Additionally, the narrow and elongate outline of many *Exilia* species resembles other gastropods belonging to other genera in various families (e.g., fusinids and fasciolariids) (Bentson, 1940: 204). Most of the extinct species of *Exilia* are based on only a few specimens although, in some cases, a substantial number (e.g., 20 to 40) of specimens is available. Specimens are commonly broken or poorly preserved.

Bentson (1940) reported on all the American and European species of *Exilia* and emphasized their morphology and stratigraphic distribution. Based on measurements given by Bentson (1940) and Kantor et al. (2001), Paleogene *Exilia* have the smallest shells of all the species of *Exilia*. Bentson (1940) also commented briefly on the biogeography and ecology of *Exilia*.

Kantor et al. (2001) used anatomical studies to significantly revise the systematics of this genus, synonymized many nominal genera with *Exilia*, provided useful digital images of some fossil and modern-day species, and commented on the biogeography and ecology of this genus. Cretaceous and early Paleogene *Exilia* lived in

upper and middle shelfal depths near the southern border of the "North Temperate Realm," and the first relatively deep water (lower shelf to bathyal) occurrences of this genus did not take place until the late Eocene. Today, the genus is confined to bathyal depths at tropical latitudes and in the New Zealand region (Kantor et al. 2001).

There has been confusion concerning *Exilia pergracilis* Conrad (the type species) and *Paleorphaphis pergracilis* Aldrich, (1886: 22, pl. 5, fig. 18) because of them having similar shells, the same species name (Bentson, 1940: 206–207), Paleogene age, and occurrence in Alabama. Kantor et al. (2001) regarded *Paleorhaphis* Stewart, 1927 as a junior synonym of *Exilia*, and, in so doing, made *Exilia pergracilis* (Aldrich, 1886) a secondary homonym of *Exilia pergracilis* Conrad, 1860.

Exilia stechesonae new species Squires
(Figures 2–19)

Paleofusimitra n. sp. Saul and Alderson, 1981: 36, pl. 3, fig. 8; Squires and Saul, 1981: 131.
Graphidula? n. sp. Stecheson, 2004: 91–92, pl. 3, figs. 8, 9.

Diagnosis: *Exilia* with medium shell size, spire high with narrow spire angle (13° to 17°), teleoconch whorls (about seven) lowly convex to somewhat flattened, sculpture weak (can be missing on parts of penultimate and last whorls), axials widely spaced, spirals narrower and closely spaced, cancellate sculpture (minute) can be present, aperture narrow and slightly upturned (but untwisted) dorsally at its anterior end, columella with one or two very small concealed plaits spaced about 2.5 mm apart.

Description: Shell up to 78.2 mm height and 15.8 mm width (same specimen); height to width ratio approximately 4.5 (most complete specimen); fusiform. Spire high, spire whorls tall. Protoconch missing. Spire angle 13° (adult specimens) to 17° (juvenile specimens). Teleoconch up to approximately seven whorls (estimated maximum of eight teleoconch whorls). Whorls lowly convex (can be somewhat flattened). Suture impressed to indistinct, with or without shell material extending slightly over suture region. Sculpture overall weak, locally can be absent. Axial sculpture consisting of weak, widely to irregularly spaced narrow ribs, extending from suture to suture. Spiral sculpture consisting of weak, closely spaced narrow ribs present on most of teleoconch whorls (on some specimens spiral sculpture can be missing on anterior two-thirds of penultimate and last whorls). Cancellate sculpture (minute) can be present. Aperture narrow and slightly upturned (but untwisted) dorsally at its anterior end. Siphonal canal narrow, with siphonal notch very small and narrow. Inner lip (columellar lip) with light callus. Columella generally straight, with one or two very small concealed plaits, spaced about 2.5 mm apart, and with variation as to which one is stronger. Outer lip thin and smooth. Growth line slightly sinuous on last whorl; slightly prosocline near suture, very slightly and

broadly opisthocline across weak angulation on posterior third of last whorl; and slightly prosocline on neck.

Holotype: LACMIP 10496 [ex hypotype LACMIP 10496], height 66.5 mm (incomplete with uppermost spire and anterior end of aperture missing), width 14.6 mm (Figures 2–5).

Paratypes: LACMIP 14748–14757.

Type Locality: LACMIP 10715. See Squires (1981: insert) for the location of this locality plotted on a topographic base map.

Geologic Age: Late early to early late Campanian.

Distribution: UPPER LOWER CAMPANIAN: Chatsworth Formation, Bell Canyon, Simi Hills, Ventura Co., southern California. MIDDLE CAMPANIAN: Chatsworth Formation, upper Dayton Canyon, Simi Hills, Los Angeles Co., southern California. LOWER UPPER CAMPANIAN: Williams Formation, Pleasants Sandstone Member, near mouth of Bee Canyon, Santa Ana Mountains, Orange Co., southern California.

Etymology: The new species is named for Mary S. Stecheson, in recognition of her study of the systematic paleontology of the gastropod fauna of the Chatsworth Formation. **The senior author, Squires, is the sole author of this new species.**

Discussion: Forty specimens were examined: 38 from the Chatsworth Formation in Dayton Canyon; one specimen from the Chatsworth Formation in Bell Canyon; and one specimen from the Williams Formation (Pleasants Sandstone Member) in Bee Canyon. All the specimens are weathered, and the sculpture, especially the axial ribs, is commonly subdued as a result. All specimens are incomplete, most likely the result of damage during collecting. No specimens have the protoconch or uppermost spire present. The anterior tip of the shell is commonly also missing. About 16 Chatsworth Formation specimens have most of the aperture present. The somewhat crushed figured specimen (Figures 9, 10) from the Williams Formation has the best preservation of the details of the sculpture. A few of the specimens are steinkerns, and some have large portions of the shell missing. Although none of the specimens are in the best possible state of preservation, the preservation is good enough to show the most important morphological characteristics.

The largest specimen (Figure 8) of the new species is from Dayton Canyon and is 78.2 mm height (incomplete), 17.4 mm width, with an estimated complete height of 80 mm. The new species is one of the tallest Late Cretaceous ptychatractids. *Exilia melanopsis* (Conrad, 1860) from the Late Cretaceous (Maastrichtian) of Tennessee is approximately the same height as *E. stechesonae*. In comparison, most other species (e.g., those illustrated by Kantor et al., 2001) of Late Cretaceous *Exilia* are small to moderate in size (19 to 48 mm height).

Exilia stechesonae with its narrow spire angle, lowly convex whorls, weaker sculpture, and narrow aperture differs from most other species of *Exilia*. The new species is somewhat similar to some *Exilia* in terms of the height to width ratio of approximately 4.5, relatively narrow spiral angle, lowly convex whorls, subdued sculpture, and a narrow aperture. An example of one of these somewhat similar species is *Exilia clarki* Bentson (1940: 215–216, pl. 2, figs. 2, 3, 8, 12, 15, 17, 19, 20) from the upper middle Eocene Cowlitz Formation in southwestern Washington. The new species differs by having a much larger shell, slightly upturned anterior end, and much less prominent axial ribs. The degree of the prominence of the axial ribs on the new species, however, is difficult to assess because of the effects of weathering.

Saul and Alderson (1981) regarded the new gastropod described here as belonging to genus *Paleofusimitra* Sohl, 1963, which they questionably assigned to family Mitridae Swainson, 1831. *Paleofusimitra* is known with certainty only from upper Campanian strata in the Ripley Formation in Mississippi, Alabama, and Georgia (Sohl, 1963, 1964). Sohl (1963, 1964) and Cernohorsky (1970: 26, 39, pl. 4, figs. 6, 7) assigned *Paleofusimitra* to the mitrids. Cernohorsky (1970: 26) mentioned, furthermore, that *Paleofusimitra* is one of the earliest mitrids retaining some of the fasciolariid features. Cernohorsky (1976: 512, pl. 462) reported that if *Paleofusimitra* is a mitrid, it is the most primitive one and retained strong fasciolariid features (e.g., placement and number of the columellar folds). The new species differs from *Paleofusimitra* by having a much larger size, a narrower pleural angle, narrower posterior part of the last whorl, narrower anterior part of the aperture, presence of axial ribs, more numerous and more closely spaced spiral ribs near suture, wider range of number of plaits, and absence of a slight siphonal fasciole.

The new species resembles superficially specimen VIPM 052 of the so-called *Nonacteonina* sp. of Ludvigsen and Beard (1994: 95, fig. 60, in part; Ludvigsen and Beard, 1997: 115, fig. 71, in part) from the Northumberland Formation at Collishaw Point, north end of Hornby Island, off the east coast of Vancouver Island, British Columbia, Canada. Katnick and Mustard (2003) assigned the rocks at Collishaw Point to the upper Campanian Northumberland Formation. The aperture of specimen VIPM 052 is not present. The new species differs by having a slightly wider spiral angle (13° to 17°, rather than 8° to 11°), less convex whorls, presence of axial ribs, and a less prosocline growth line near the suture.

area. Raymond Graham (Victoria, British Columbia) provided stratigraphic and locality data concerning specimen VIPM 052 and also took digital images of this specimen for comparative purposes. Lindsey T. Groves and an anonymous person critically reviewed the manuscript and gave valuable comments.

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APPENDIX 1
LOCALITIES OF THE NEW SPECIES

All quadrangles listed below are U. S. Geological Survey, 7.5 minute, topographic maps. For the Chatsworth Formation localities, see Squires (1981) for Simi Hills locations plotted on a topographic base map.

LACMIP 10710 [= CIT loc. 1158], southeast slope of Simi Hills, north bank of Bell Canyon, Chatsworth Formation, Ventura Co., southern California, Calabasas Quadrangle, United States Geological Survey. Age: Late early Campanian. Collectors: W. P. Popenoe, L. R. Saul, J. Alderson, 1935–circa 1990.

LACMIP 10715. [= locs. CIT 1159, UCLA 6965, and CSUN 175], 34°13'12.02"N, 118°40'3.63"W, prominent fossil bed on crest of spur between forks of Dayton Canyon about 122 m east of the Los Angeles–Ventura Co. line, Chatsworth Formation, Dayton Canyon, southeast slope of Simi Hills, Los Angeles Co., California, Calabasas Quadrangle. Age: Middle Campanian. Collectors: R. Durbin, W. P. Popenoe, L. R. Saul, J. Alderson, R. L. Squires, 1935–circa 2000.

LACMIP 42320. Temporary exposure made during construction of the Foothill Transportation Corridor (Toll Road Highway 241), Williams Formation, Pleasants Sandstone Member, elevation 715 ft., 425 m due south of hill 923, west side of Bee Canyon near its mouth, western foothills of Santa Ana Mountains, Orange Co., southern California, El Toro Quadrangle. Age: Early late Campanian. Collector: P. Peck, July 17, 1997.

A new species of Fissurellidae (Gastropoda: Vetigastropoda) from the deep–sea off the eastern Pacific coast of Mexico

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ABSTRACT

The present article describes *Fissurella hendrickxi*, a new deep-sea gastropod species found off the Pacific coast of Mexico (Baja Peninsula; Gulf of California), at 650–837 m depth, collected by the TALUD XV and TALUD X projects. *Fissurella hendrickxi* was classified according to shell sculpture, radula, epipodium, and ctenidial structure. It is remarkable for its very thin shell, which covers the entire animal.

Additional Keywords: Deep sea, *Fissurella*, continental slope

INTRODUCTION

Recent surveys of deep-water environments off the Pacific coast of Mexico have discovered new molluscan species. Such studies seldom yield mollusk samples, because available sampling techniques are not always adequate or only few sediment samples are collected, thus preventing a thorough inventory of the continental shelf, slope, and the abyssal plain (Zamorano et al., 2013; McLean and Geiger, 1998).

The Fissurellidae comprises four subfamilies: Fissurellinae, Diodorinae, Emarginulinae, and Hemitominae, with Fissurellinae containing six genera, which are diagnosed by shell and radular characters (Thiele, 1891; 1912; 1929; McLean, 1984a; 1984b; Hickman; 1998). Members of the Fissurellidae are most frequently found in the intertidal or shallow waters worldwide and are not as prevalent in deep waters. Some genera and species of Fissurellidae have been recorded in deep waters of the eastern Pacific off South America (McLean and Geiger, 1998; Araya and Geiger, 2013). McLean (1971) documented deep-water Fissurellidae species [*Emarginula velascoensis* Shasky, 1961, *Zeidora flabellum* (Dall, 1896), and *Cranopsis expansa* (Dall, 1896)] in the Gulf of California and/or along the Baja Peninsula with bathymetric ranges around 200 m.

MATERIALS AND METHODS

The new species was collected during the TALUD X and TALUD XV projects (2007 and 2012), on board the Universidad Nacional Autónoma de México (UNAM) research vessel EL PUMA along the western coast of Baja California Sur and in the Gulf of California. Station depths were estimated with a SIMRAD echo-sounder. Temperature and dissolved oxygen measurements were collected 20 m above the seafloor with a Seabird CTD multisensor probe. Oxygen measurements were checked by titration (Strickland and Parsons, 1972). Morphological descriptions include the following dimensions: length (L), width (W), and height (H). Fixed specimens were photographed for their external anatomy. Specimen preparation and SEM imaging were performed following Geiger et al. (2007). Cross sections of shells were imaged from broken pieces. Measurements were taken from a middle section and a section containing the parts of the foramen.

Specimens are deposited at the Santa Barbara Museum of Natural History (SBMNH), and the Regional Collection of Marine Invertebrates at the Mazatlán Marine Station, UNAM, in Mazatlán, Mexico (EMU-ICML).

Abbreviations used in the figures are: **an:** anus; **ct:** cephalic tentacle; **et:** epipodial tentacle; **ey:** eye; **fo:** foramen; **ft:** foot; **gi:** gill; **gs:** gill suspensory stalk; **mb:** mantle border; **mt:** mantle tentacles; **mo:** mouth; **sn:** snout.
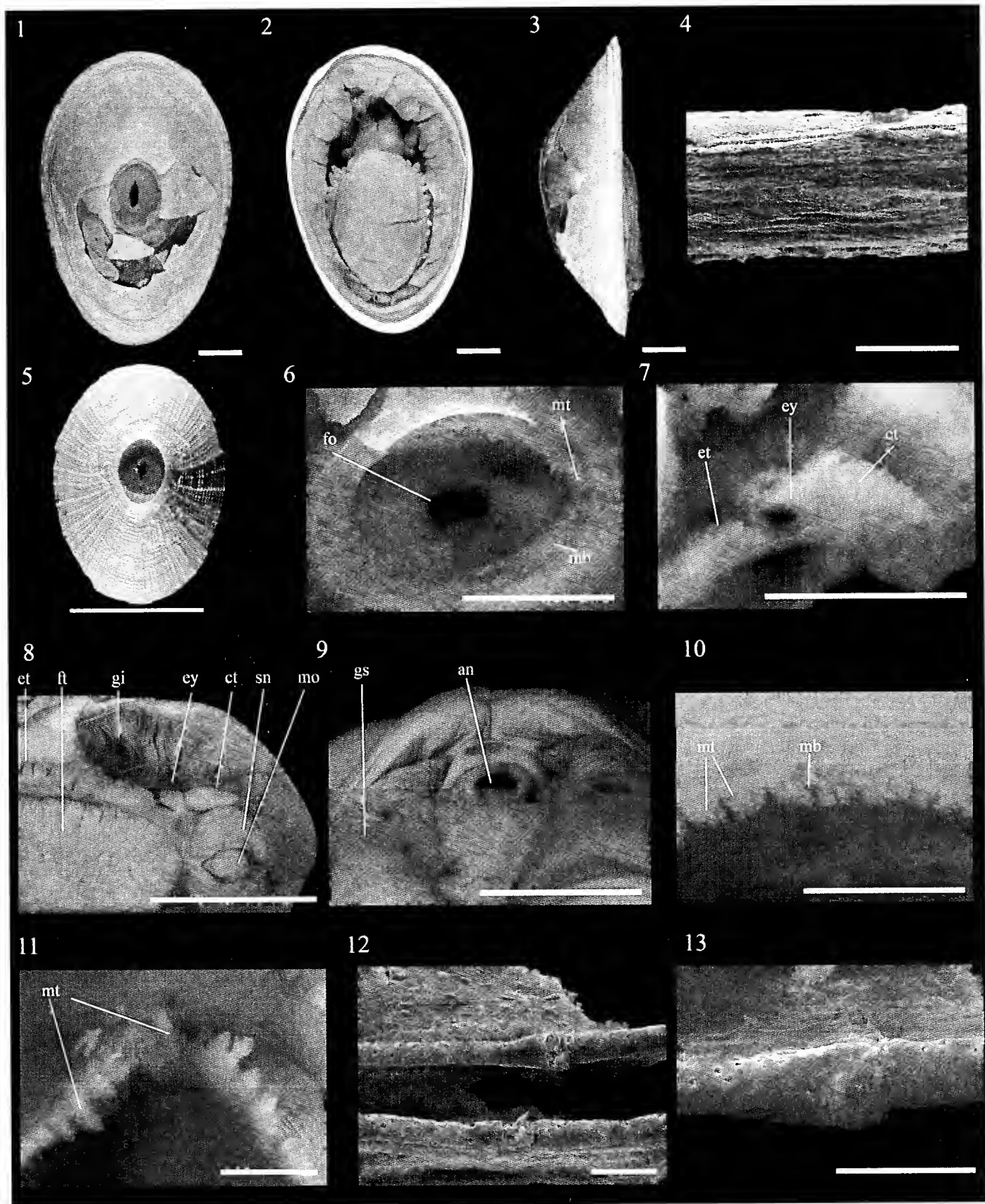
SYSTEMATICS

Class Gastropoda Cuvier, 1797
Suborder Vetigastropoda Salvini–Plawen, 1980
Family Fissurellidae Fleming, 1822
Subfamily Fissurellinae Fleming, 1822
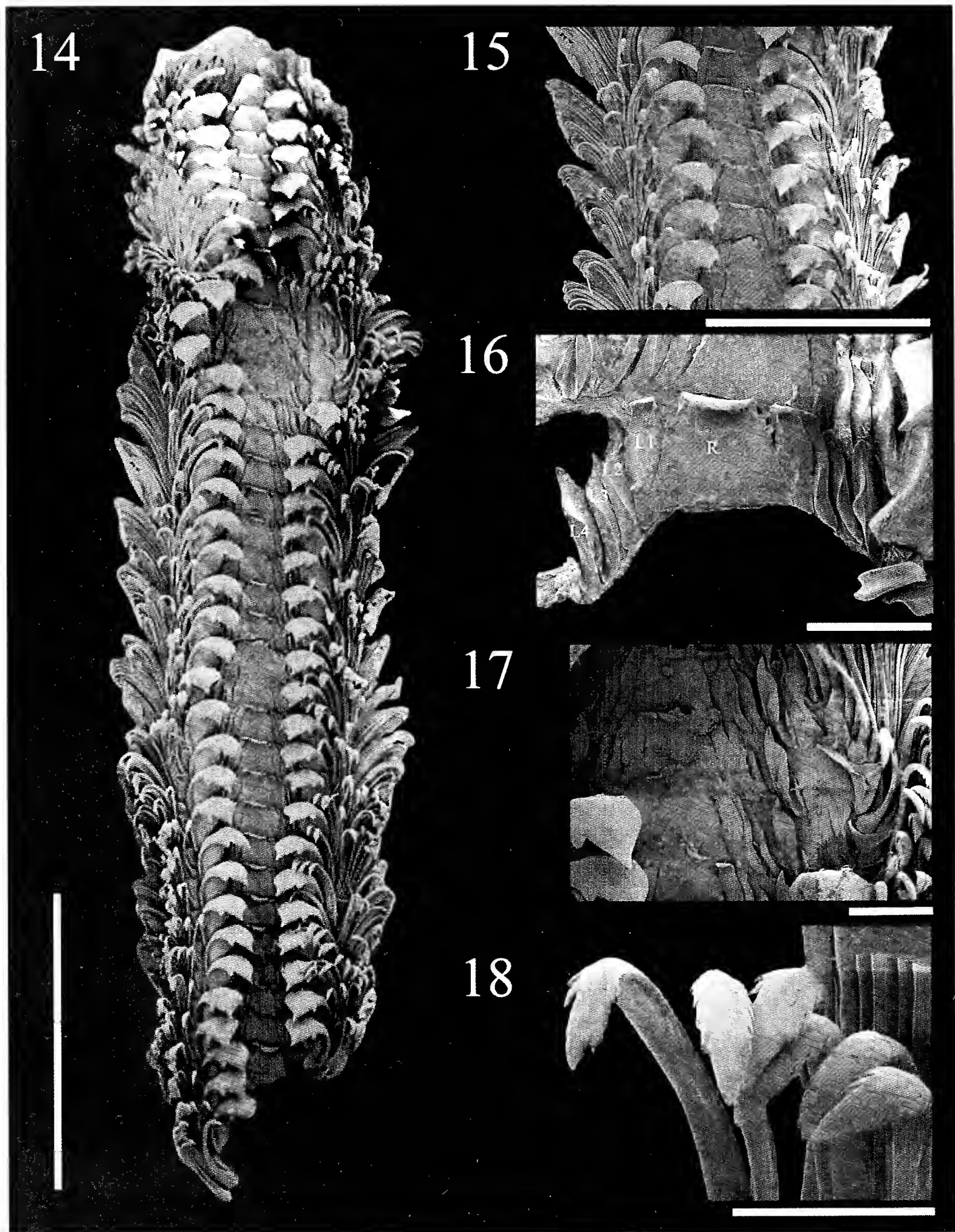
Genus *Fissurella* Bruguière, 1789

Type Species: *Fissurella nimbosa* Linnaeus, 1758 (by monotypy).

Fissurella hendrickxi new species
(Figures 1–18)

Diagnosis: Shell up to 42.9 mm; foramen eliptical, central. Shell extremely thin (~0.1 mm). Specimens smooth

Figures 1–13. *Fissurella hendrickxi* **new species.** Holotype, SBMNH 457424. **1.** Dorsal view. Scale bar = 10 mm. **2.** Ventral view. Scale bar = 10 mm. **3.** Holotype, lateral view. Scale bar = 10 mm. **4. S**hell thickness (SEM). Scale bar = 100 μm. **5.** *Fissurella hendrickxi* **new species** (small specimen), EMU-1CML 11338. Scale bar = 10 mm. **6.** Foramen with tentacles and remnants of shell. Scale bar = 5 mm. **7.** Detail of eye, cephalic tentacle and epipodial tentacle. Scale bar = 5 mm. **8.** Right gill, epipodium, foot, eye, cephalic tentacle, snout, and month. Scale bar = 10 mm. **9.** Rectal opening with granular fecal matter. Scale bar = 5 mm. **10.** Mantle border and mantle tentacles above foot. Scale bar = 2 mm. **11.** Enlargement of posterior tentacle surrounding foramen. Scale bar = 1 mm. **12.** Bursicle. Scale bar = 100 μm. **13.** Enlargement of bursicle. Scale bar = 100 μm.

Figures 14–18. *Fissurella hendrickxi* **new species.** Radula under SEM. Paratype SBMNH 235544. **14.** Entire radula. Scale bar = 2 mm. **15.** Whole width of radula. Scale bar = 1 mm. **16.** Central field with rachidian tooth and lateral teeth. Scale bar = 200 μm. **17.** Lateromarginal plate. Scale bar = 200 μm. **18.** Marginal teeth. Scale bar = 100 μm.

due to erosion at top, concentric lines at shell bases, small specimens with primary and secondary cords. External shell color dull whitish.

Description: Shell height moderate (about 30% of length), outline elliptical, a bit narrow at posterior end (Figures 1–3). Width about 60–70% of length. Foramen central and conical, 20–22% of length (Figures 6). Shell extremely thin (Figure 4): callus of foramen 0.16–0.17 mm reminder of shell 0.1 mm. Profiles straight. Radial sculpture of alternating primary, secondary cords regularly spaced. Concentric sculpture generally weak, strongest close to edges. Larger specimens with concentric lines at shell bases, radial sculpture absent. Small specimens with radial and concentric sculpture (Figure 5). Foramen area eroded. Color external dull whitish; inner surface whitish, glossy.

HEAD AND FOOT (Figures 7–9):

Eyestalk narrower than cephalic tentacles, approximately ¼ of cephalic tentacle length, located just posterior to origin of cephalic tentacles. Eye almost half as wide as diameter of eyestalk. Snout cylindrical, tapering, surrounding central mouth. Epipodium with approximately 34–36 tentacles arranged in single horizontal row terminating at neck; tentacles varying in size by factor two, larger ones approximately as long as eyestalk. Cephalic

Figure 19. Distribution of sampling stations where specimen of *Fissurella hendrickxi* new species were collected during the TALUD XV and X surveys off the western coast of the Baja California Peninsula and Gulf of California (▲ = type locality).

tentacle located on each side of snout, each tentacle tapering gradually (wider at base than at tip), tip pointed, with different folds around tentacle, slightly shorter than snout. Foot thick, 60% of the shell length.

MANTLE ORGANS (Figures 10–13):

Mantle margin close to shell, smooth exterior fold, interior fold wider than middle fold; mantle tentacles in middle fold; mantle margin of foramen similar. Gill hypertrophied, filaments symmetrical, with rounded tip; bursicles present. Anus elliptical, located at posterior end of pallial cavity.

RADULA (Figures 14–18):

Rachidian tooth trapezoidal, broad. Five lateral teeth, with narrow inner teeth. Lateromarginal plate triangular, without projections, sinuous distal edge. Marginal teeth with spoon-shaped pointed tip, with fine denticles on each side of the apical margin.

Type Material: Holotype SBMNH 457424: 34.7× 10.6×22.7 mm (L×W×H), 4 **paratypes**, all from type locality: SBMNH 235544: 42.9×11.5×22.3 mm, 32.9× 10.93×22.0 mm (L×W×H), EMU–ICML 10965: 35.6× 22.3×11.9 mm (L×W×H), EMU–ICML 10966: 30.2× 20.7×8.2 mm (L×W×H).

Type Locality: Baja California Sur Peninsula, Mexican Pacific, Mexico, TALUD XV, St. 5D, 23°16′58″ N; 110°20′42″ W, 650–665 m (Figure 19).

Other Material Examined: Seven specimens, EMU-ICML 11338, TALUD XV st. 5D, Baja California Sur Peninsula, Pacific Ocean, Mexico, 23°16′58″ N, 110°20′42″ W; one specimen, EMU-ICML 11339, TALUD XV, St. 20, Baja California Sur Peninsula, Pacific Ocean, Mexico, 26°30′42″ N, 113°56′0″ W; one specimen, EMU-ICML 11340, TALUD X, St. 5, Gulf of California, Mexico, 28°14′50″ N, 112°24′53″ W.

Environmental Conditions: Dissolved oxygen, 0.08–0.15 mlO$_2$/l; temperature, 6.2–8.4°C; salinity, 34.55–34.68‰.

Etymology: Named after Michel E. Hendrickx (Instituto de Ciencias del Mar y Limnologia, Mazatlán, Sinaloa, México), who for long time has long studied the benthic fauna of the eastern Pacific Coast of Mexico, in particular from off the Baja Peninsula and the Gulf of California.

Comparisons: The radula with very large lateral tooth 5, whose tip aligns with the lateral teeth of the subsequent row (see McLean and Kilburn, 1986) places our species in Fissurellinae, and not in Emarginulinae, which includes the genus *Stromboli*. The absence of an internal thickening around the foramen differentiates the species from the otherwise similar *Diodora*. Among the genera in Fissurellinae, genera other than *Fissurella* either exhibit strong shell reduction (*Amblychilepas*, *Leurolepas*,
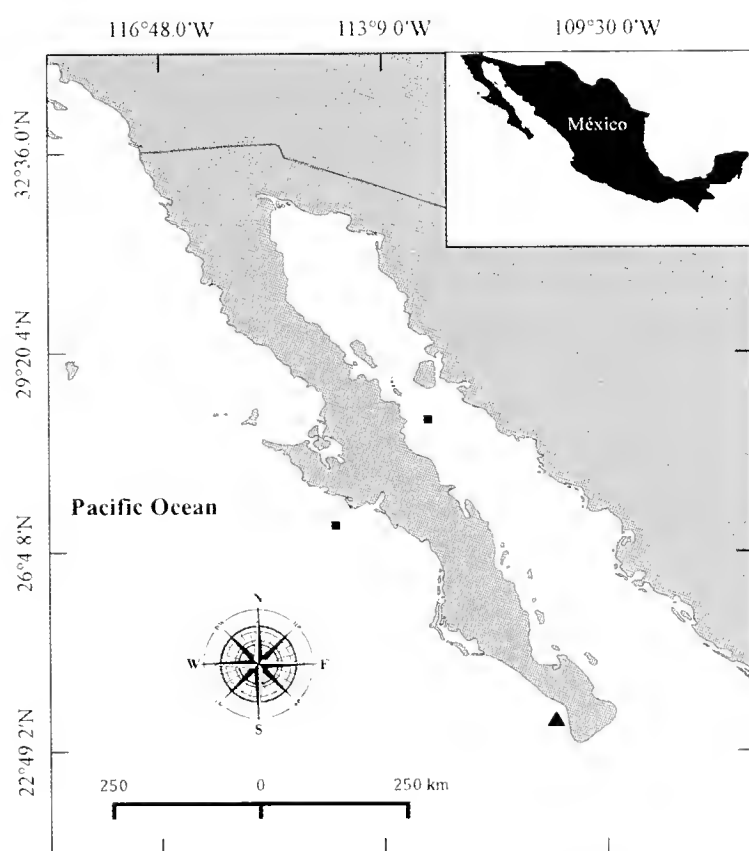
Macroschisma), or show strong propodial elaborations (*Dendrofissurella*). All approximately 46 recent species of *Fissurella* have much thicker shells than the new species.

The two species overall most similar to *Fissurella hendrickxi* are in genera other than *Fissurella*; these are *Diodora codoceoae* (McLean and Andrade, 1982) and *Stromboli beebei* (Hertlein and Strong, 1951). They share a large and thinner than usual shell with a large foramen that is conical in shape, and the interior shell color is white. *Diodora codoceoae* and *S. beebei* differ from the *F. hendrickxi* in their fleshy mantle that fully envelops the edge of the shell and radial ribs that are uniformly fine, with no distinction between primary and secondary ribs (McLean and Andrade, 1982). They both also have a much sturdier shell than *F. hendrickxi* and the sculpture is stronger in *S. beebei* and *D. codoceoae*. The shells of both species are noticeably thicker: *D. codoceoae* 1.05 mm at length of 36.5 mm (SBMNH 172216); *S. beebei* 1.03 mm at length of 31.75 mm (SBMNH 118681).

Remarks: *Fissurella hendrickxi* was collected just below the oxygen minimum zone < 0.5 ml O_2/l (OMZ); fully oxygenated seawater can hold >7 ml O_2/l (Levin 2002). While the oxygen measurements were taken some 20 m above the sea floor (due to equipment limitations), it gives a reasonable indication of the conditions prevailing in the species habitat.

Shell sculpture changes with growth. Small specimens (smallest specimen 18 mm) have radial and concentric elements whereas larger (>35 mm) specimens only have concentric sculpture at the shell margin. This difference may be accounted for by erosion and/or physical wear of the shell. However, low carbonate assimilation levels or adaptive changes among large organisms may also play a role.

The epipodium, a complex of sensory or tactile structures located on the sides of the foot under the shell margin of the vetigastropods (Macdonald and Maino, 1964; Cox, 1962; Crisp, 1981), has proven useful in taxonomic and systematic classification (Hickman and McLean, 1990, Geiger, 1999; Collado, 2008; Collado et al., 2012). The epipodium of *F. hendrickxi* is particularly well-developed compared to other species in the genus. This enlargement may be an adaption to extreme environmental conditions such as low oxygen concentrations or depth. Alternatively, it may improve mobility and tactile sensitivity in soft sea-beds.

DISCUSSION

The diversity of deep-sea mollusks in the Pacific coast of Mexico is not well documented. Most species of Fissurellidae from that area occur in relatively shallow water (0–50 m) on hard substrates. Few deep-water and soft sea-bed species are known [e.g., *Cornisepta guzmani* Araya and Geiger, 2013; *C. pacifica* (Cowan, 1969); *C. levinae* McLean and Geiger, 1998; *C. uirapa* Simone and Cunha, 2014].

Fissurella hendrickxi was found in an environment under hypoxic conditions, which characterizes this region of the eastern Pacific, where the oxygen minimum zone exhibits significant latitudinal variations in depth, thickness, and intensity (Helly and Levin, 2004). Whether the enlarged epipodium in the species is an adaptation to deep-water conditions remains unknown. The comparatively large gill is remarkable, and additional, indirect evidence that the species may be adapted to that particular environment.

Specimens described here were collected from the continental slope region at depths >200 m. Larger organisms feature decreased shell thickness, a potential adaption to low energy environments. McLean (1984c) noted that the limpet shape may prove advantageous, as it provides protection through clamping against the substratum. Species living on soft bottoms can no longer clamp down, and the protective function of a thick shell does no longer apply.

Fissurellidae is an interesting lineage with respect to shell reduction, including complete loss of the shell in *Buchanania*. Reduction of shell thus far has mostly been achieved by reduction in size while maintaining shell thickness. Examples of moderate reduction include *Megathura* and *Scutus*, while extreme reduction is encountered in *Macroschisma*. *Fissurella hendrickxi*, on the other hand, has reduced shell thickness while retaining a large size. It is the only species in Fissurellinae with fully grown shell so thin that it does not offer any protective function anymore (The specimens recovered had gonads indicating maturity.) Similarly thin shells are only known from deep-water *Emarginulinae*, but those are overall much smaller (~2–10 mm: McLean and Geiger, 1998).

ACKNOWLEDGMENTS

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Notice

FLORIDA UNITED MALACOLOGISTS 2018

The ninth meeting of Florida United Malacologists (FUM 2018) will take place on Saturday, January 27, 2018, at the Bailey-Matthews National Shell Museum on Sanibel Island, Florida. The one-day gathering brings together researchers, citizen scientists, and students interested in a broad swath of mollusk-related topics. FUM follows the pattern of similar informal gatherings such as BAM (Bay Area Malacologists), SCUM (Southern California United Malacologists), MAM (Mid-Atlantic Malacologists), and OVUM (Ohio Valley United Malacologists). The event circulates among different Florida organizations, but usually takes place at the Shell Museum every other year. Presentations are limited to 15 minutes plus 5 minutes for questions. Presenters are required to submit a brief abstract limited to 150 words or less. The gathering will be free to presenters and pre-registered participants. Box lunches and dinner at a local restaurant (to be arranged) will be available to participants and presenters. The deadline for abstract submission is December 31, 2017.

For registration and further information, visit http://shellmuseum.org/about/news/florida-united-malacologists-2018, or email jleal@shellmuseum.org.

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NEW TAXA PROPOSED IN VOLUME 131

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The Nautilus publishes articles on all aspects of the biology, paleontology, and systematics of mollusks. Manuscripts describing original, unpublished research and review articles will be considered. Brief articles, not exceeding 1000 words, will be published as Research Notes and do not require an abstract.

Manuscripts: Each original manuscript and accompanying illustrations should be submitted to the editor via e-mail. Authors should follow the general recommendations of Scientific Style and Format—The CSE Manual for Authors, Editors, and Publishers, available from the Council of Science Editors at http://www.scientificstyleandformat. org/Home.html.

The first mention of a scientific name in the text should be accompanied by the taxonomic authority, including year. Metric, not English, units are to be used. The sequence of sections should be Title, Author(s) and Affiliations, Abstract, Additional Keywords, Introduction, Materials and Methods, Results, Discussion, Conclusions, Acknowledgments, Literature Cited, Tables, Figure Captions, Figures. If the author for correspondence is not the senior author, please indicate in a footnote. The abstract should summarize in 250 words or less the scope, main results, and conclusions of the article. Abstracts should be followed by a list of additional keywords. All references cited in the text must appear in the Literature Cited section and vice-versa. Please follow a recent issue of *The Nautilus* for bibliographic style, noting that journal titles must be unabbreviated. Information on plates and figures should be cited only if not included within the pagination of cited work. Tables must be numbered and each placed on a separate page. If in doubt, please follow a recent issue of the journal for sequence of sections and other style requirements.

Illustrations: Illustrations are rendered either at full-page width (maximum width 17 cm) or column width (maximum width 8.2 cm). Please take these dimensions into consideration when preparing illustrations. Page-width illustrations ideally should span the entire width of printed page (17 cm). "Tall" page-width illustrations should be avoided, square or "landscape" formats work better. Please design plates accordingly, such that there will be enough space left at the bottom of printed page for plate caption. (Digital technology has made this task much easier.)

All line drawings must be in black, clearly detailed, and completely labeled. Abbreviation definitions must be included in the caption. Line drawings must be high resolution fi les at least 600 dpi (dots per inch) resolution at actual size. Standard digital formats for line drawings include .tif, .bmp, .psd, .eps, and .pdf.

Photographs may be submitted in black-and-white or color, preferably in RGB mode if in color. Standard digital formats for photographs include .tif, .psd, .jpg, or .pdf. Photographs must be high resolution files at least 300 dpi resolution at actual (printed) size.

If more than one figure is included in an illustration, all figures are to be consecutively numbered (Figures 1, 2, 3, . . . , NOT Figures 1A, 1B, 1C, . . . , NOR Plate 1, Figure 1, . . .). In illustrations with more than one figure, make sure that blank areas between figures should be kept to a minimum, thereby allowing for more area for each individual figure.

Compressed (e.g., .jpg) or other low-resolution file formats may be used to facilitate original submission and the review process, but may not be acceptable at final submission (see below).

Types and Voucher Specimens: Deposition of the holotype in a recognized institutional, public collection is a requirement for publication of articles in which new species-level taxa are described. Deposition of paratypes in institutional collections is strongly recommended, as is the deposition of representative voucher specimens for all other types of research work.

The Editorial Process: Upon receipt, all manuscripts are assigned a number and acknowledged. The editor reserves the right to return manuscripts that are substandard or not appropriate in scope for journal. Manuscripts deemed appropriate for the journal will be sent for critical review to at least two reviewers. The reviewers' recommendations will serve as basis for rejection or continuation of the editorial process. Reviewed manuscripts will be sent back to authors for consideration of the reviewers comments. The revised version of the manuscript may at this point be considered accepted for publication by the journal.

Final Submission: Authors of accepted manuscripts are required to submit a final version to the editor at jleal@ shellmuseum.org. High-resolution image files may be sent to the editor at this stage.

Proofs: After typesetting, proofs will be sent to the author. Author should read proofs carefully and send corrections to the editor within 48 hours. Changes other than typesetting errors will be charged to the author at cost.

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More information at http://shellmuseum.org/learn/the-nautilus.